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THE

GEOLOGY OF SCOTLAND,

AND ITS ISLANDS;

WITH A COLOURED GEOLOGICAL MAP, AND
NUMEROUS SECTIONS.

By WILLIAM RHIND,
MEMBER OF THE ROYAL MEDICAL AND ROYAL PHYSICAL SOCIETIES;
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OF THE ENVIRONS OF EDINBURGH.

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PREFACE.

THE increasing taste for Geological studies, both as a subject of general interest and practical utility, has, of late, awakened a strong desire for information regarding the Geology of Scotland.

With a view of gratifying this desire, in some measure, and of connecting the study of the Geology with the Geography of our country, the following Sketch of the General Geology of Scotland, and its Islands, has been undertaken.

Notwithstanding the researches of several eminent geologists in detached districts, much of the particular and local Geology of Scotland remains yet to be explored. Of the labours of his predecessors, the author, as will be seen in the marginal references of these pages, has frequently availed himself, more particularly of the descriptions of some few localities which he has not himself personally inspected.

The limits of the present work necessarily preclude any thing like minute detail, yet a connected view of what is already known may not only prove acceptable and useful to the general reader, but may serve to facilitate the investigations of the local student.

CONTENTS.

Page

GENERAL ASPECT AND CLIMATE, . . . 1

GENERAL VIEW OF THE SCOTISH STRATA, . . 9

GEOLOGY OF THE COUNTIES, . . . 18

GREYWACKE DISTRICT, ... ib.

- Wigton and Kirkcudbright Shires, . . ib.
- Dumfries-shire, ... 21
- Lanark, Peebles, and Selkirk Shires, . . 31
- Roxburgh and Berwick Shires, . . . 32
- Haddingtonshire, ... 35
- SCOTISH COAL-FIELD, ... 36
- Edinburghshire, ... 41
- Linlithgowshire, ... 52
- Fifeshire, ... ib.
- Clackmannanshire, ... 56
- Stirlingshire, ... 59
- Lanarkshire, ... 60
- Renfrewshire, ... 65
- Ayrshire, ... 68
  - *Ailsa Rock*, ... 72

PRIMARY CENTRAL DISTRICT, ... 73

- Glen Tilt, ... 74
- Perthshire, ... 75
  - *Kinnoul Hill*, ... 76
- Argyleshire, ... ib.
  - *Bencruachan*, ... 77

Page
Ben Nevis, ... 80
Glen Roy, ... 83
OLD RED SANDSTONE DISTRICTS, . . 87
Forfarshire, ... *ib.*
Aberdeenshire, ... 97
Banffshire, ... 99
Elginshire, ... 100
Sands of Culbin, ... 105
Inverness-shire, ... 110
Cromartyshire, ... 111
Sutherlandshire, ... 114
Brora, ... *ib.*
Caithness-shire, ... 119
Western Coasts of Ross and Sutherland Shires, . 122
THE WESTERN ISLANDS, . . . 125
The Gneiss Islands, . . . 126
The Trap Islands, ... 131
Skye, ... 132
Staffa, ... 138
The Schistose Islands, ... 143
The Clyde Islands, ... 149
Arran, ... *ib.*
Bute, ... 155
Orkney Islands, ... 160
Shetland Islands, ... 161

THE

GEOLOGY OF SCOTLAND.

GENERAL ASPECT AND CLIMATE.

SCOTLAND is of an oblong, irregular form, extending longitudinally due north and south about 280 miles, and varying in breadth from 130 miles to 100, 50, and 40 miles. The greater part of the surface is irregularly elevated into mountain and valley, a very small proportion extending into continuous plains. The eastern side is bounded by a well-defined continuous waving line of coast, indented by the three great estuaries of the Forth, Tay, and Murray Friths. The western line again is exceedingly irregular, being broken up by innumerable headlands and bays, and thickly studded with islands of various magnitudes. The country, for the purpose of Geographical arrangement, has been portioned out into a southern division, including that part of the country south of the Frith of Forth, a middle division, containing the space between the Firth of Forth and the Murray Frith, a northern division, embracing the whole north-west portion of Scotland, and the islands, consisting of several groups surrounding the mainland.

Geologically viewed, the country may be divided into the *great primary* or Alpine range, extending from the coast of Argyleshire on the south-west, and following the course of the Grampian mountains north-eastward into Aberdeenshire; and, on the other hand, the mountain ranges of Inverness and Ross, stretching towards the north-west into the northern boundaries of Sutherlandshire; *the secondary range,* including the *greywacke formation* of the southern district; the *old red sandstone formation,* forming the valleys and coast lines on each side of the primary mountains; and *the great coal formation,* extending from the Frith of Forth on the east, to the Lanarkshire and Ayrshire coasts on the west.

The middle or Alpine region is the most elevated portion of Scotland; and, generally speaking, the greatest elevation exists towards the western and northern coasts, while the country slopes gradually towards the east. The Alpine range commences in the west with high mountains, which tower abruptly from almost the sea level, as Ben Nevis and Ben Cruachan, the former reaching the height of 4370, the latter the height of 2459 feet above the sea level. The chain of the Grampian mountains, including

Ben Lomond, Ben Ledi, Ben Lawers, Ben Macdhui, and the Cairngorms, stretching from south-west to north-east, continue this elevation till the country slopes into the coast levels on the Aberdeenshire and Banffshire coasts; while the elevated ridges, stretching along Inverness and Ross shires, among which are conspicuous Ben More, Ben Wyvis, and Ben Clibrick, extend the elevations north-westward to the Sutherland and Caithness coasts. South of the Grampian range, a series of minor mountain chains, having their general direction from west to east, divide the country into separate valleys, such are the Seidlaw hills in Forfarshire, the Ochils in Stirlingshire, the Pentlands in the Lothians, the Lammermoors in Berwickshire, and, lastly, the great range of the Cheviots, which separate Scotland from England.

THE CLIMATE of Scotland, like that of other localities, is not determined by its latitude alone, but is influenced by its position with regard to the ocean, by its elevation, and by its mountain ranges.

Being comparatively a narrow tract of land, surrounded on all sides by the ocean, and thus partaking throughout its whole extent of that equalizing fluid, its medium temperature indicates a degree of elevation not assignable to its actual latitude. This is shown in the mean annual temperature of the mainland, which has been estimated at about 47° to 48° Fahrenheit, but it is even more conspicuous in that of the islands, which lie considerably more to the north, the mean temperature of Orkney being about 46°, and that of the Shetland Islands 44° to 45°.* The annual temperature, too, is higher along the line of coast, and in the level and extended valleys, than in the alpine districts, the winter cold, especially, being less severe, and of shorter duration, in the former than in the latter. There is also a considerable difference in the winter temperature on the western and south-western coasts, as compared to the eastern side of Scotland. That of the western coast being modified and elevated by the genial influence of the Atlantic breezes, while the east, especially towards the spring and summer, is depressed by the chill and dry winds coming from the north-western continent of Europe. To compensate for this, however, the summer and the autumn of the western coast, as well as the islands, is kept at a lower temperature from the excess of moisture, and the interruption of the sun's rays from the frequently clouded sky.

From the same causes a greater quantity of moisture falls on the western than on the eastern coasts of the island. During a great proportion of the year the prevailing winds are from the west and south-west. These currents sweep over the Atlantic from the tropical regions, and are, consequently, of an elevated temperature, and highly charged with moisture. Arriving in the western part of the island, they are suddenly cooled down by the lower temperature of the surface of the land there, and immediately a portion of their suspended moisture is deposited; this goes on as they proceed over the country, till arriving at the eastern extremity, the lower currents are pretty nearly assimilated in temperature to the surrounding media, and the deposition of moisture then ceases. In this way, the mean annual quantity of rain which falls on the west coast, as indicated at the following localities, is, Dumfries, 36 inches; Largs on the Frith of Clyde, 43 inches; Castle Toward, Argyleshire, 50 inches; while, on the east coast, the average is only from 24 to 27 inches; being at Dalkeith, 25 inches; Edinburgh, 24; Aberdeen, 27 to 28.

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* **Mean temperature of Orkney, from 1827 to 1838, 46° 25′. Rev. C. Clouston.**

On the east coast a colder and drier current of air, coming from the north-western portion of the continent of Europe, not unfrequently prevails, which has a directly opposite influence to that of the western current. When it reaches our shores, it immediately absorbs both the moisture and warmth of our more elevated temperature, and thus has a peculiarly chilling and ungenial effect on the vegetable and animal fibre, independent even of its power of lowering the general temperature, as indicated by the thermometer.

In the intermediate spaces between the western and eastern coasts, other circumstances tend to modify the fall of rain and the temperature. The chief of which are the elevated mountain ridges and the nature of the soil and substrata. The mountain ranges which intersect Scotland, and which, as has been remarked, extend generally from south-west to north-east, exercise a marked influence on the atmospheric currents, and this not only from their height and position, forming so many funnels or tracts by which the air is mechanically conducted, but from their electric influence in attracting the currents of clouds, and their difference of temperature in condensing this vapour into rain. We accordingly find, that along the tract of these mountain ranges more rain falls than in the intervening valleys, and that towards the termination of these ranges the excess of deposition ceases. The annual amount of rain, as indicated at Kinfauns Castle near Perth, and at Clunie Manse, Perthshire, localities in the tract of the great Grampian range, is from 29 to 30 inches, while at Dundee, Montrose, and Aberdeen, the annual average does not much exceed 25 inches, the medium fall on the eastern coast.

Thus heavy falls of rain may often be seen as taking place along the range of the Ochils and Lammermoors, when not a drop has fallen during the same period in the great valley of Mid-Lothian. The coast line along the Murray Frith also being low and level, is singularly exempt from the average excess of rain which falls along the Cairngorm range to the south, or the elevated land of Sutherland to the north. The annual average of Morayshire for the last six years has been about 25 inches.

The nature of the soil and the substrata also influence the temperature of the locality, and the humidity or dryness of the atmosphere. Stiff clayey and impervious soils retain the moisture on their surface, and thus add to the ungeniality of the atmosphere, while light and porous soils imbibe the moisture, allow it to drain off, and presenting a dry porous surface favourable for absorbing the sun's heat, impart an additional temperature to the locality. In general, the primary districts, by presenting a substrata dense, compact, and impervious to water, influence the coldness and humidity of the atmosphere, while the light porous strata of the sandstone formation, with its numerous fissures, aids the transmission of water through its substrata, and is favourable to a quick evaporation from the surface, thus speedily getting free of an excess of humidity. The primary districts, too, are also generally the most elevated, and thus the temperature is diminished in the ratio of about one degree in every elevation of 270 feet.

The vegetation of the country, both natural and artificial, is of course influenced by the local causes of climate just enumerated. Thus the western and south-western portions of Scotland are celebrated for the profusion of herbage which is produced at almost all seasons of the year, and for the facilities afforded for the pasturage of cattle and sheep. The valleys of the sandstone and other secondary formations, skirting the coasts and the rich alluvial banks of the rivers and estuaries, constitute the great agricultural districts, where wheat and other grains are raised in abundance, and where the oak, beech, elm, and fruit trees, flourish in greatest luxuriance. This agricultural district is strictly limited to from 500 to 800 feet above the sea level, wheat rarely or never coming to perfection in Scotland at a height beyond these limits. Beyond the agricultural district in elevation, extends the moorland, where the hardier grasses, heather, hazel, birch, and alder flourish, extending to about 1500 feet above the sea level. Above this only alpine plants show themselves, to the height of about 2809 feet; still higher, even these give place to the mosses and lichens; and at last, a height is reached where vegetation becomes extinct altogether, as on the top of Ben Nevis, where snow lies during all the year, though not exactly reaching in altitude the calculated line of perpetual congelation.

To indicate the influence of soil and climate on vegetation, it may be remarked, that wheat is very sparingly cultivated throughout Aberdeen and Banff shires, though oats are largely raised, neither is this grain raised in the valleys of the Grampian range, as at Clova, Spittal of Glenshee, Loch Tay, Loch Earnhead, nor along the coast, from the north of Sutherland to the north-west of Argyle.

Trees of any magnitude are rarely found on the Western Islands, or in Orkney or Shetland, yet they must have grown to a great size and in great numbers on many of the more exposed localities on the mainland of Scotland in former periods, as the remains of large trunks strew the morasses and peat mosses of the north country.

Several wild animals, as the wolf, the boar, the elk, the beaver, and others, which once inhabited Scotland, are now extinct in this country; but to these circumstances we shall afterwards refer, when treating of the recent changes which have taken place in the aspect of the country.

GENERAL VIEW OF THE SCOTISH STRATA.

Before proceeding to a particular account of the separate districts of Scotland, a general view of the strata, and their order of succession, may be premised.

The primary sedimentary rocks, commencing with the lowest in position, are:—

Gneiss, mica schist, chlorite schist, quartz rock, and *clay slate.* These are found lying on granite, generally at an inclination approaching to the vertical, often curved and contorted, and not always following the exact order of position as above, but frequently alternating with each other.

These rocks occupy the greater proportion of the middle and north-western part of the mainland of Scotland, commencing on the south-east at Stonehaven, and terminating at Cape Wrath on the north-west, while they extend over an almost continuous surface to the Mull of Cantyre on the south coast, and to the western shores of Argyle and Inverness shires. Intermingled with the strata, but in comparatively small proportions, are bands of primary limestone, sometimes assuming a stratified structure and a dark or variegated hue, at other times forming masses of white compact crystalline marble, as in the valley of Glen Tilt.

Greywacke.—To these strata succeed the greywacke slates and conglomerates, but sparingly developed in the central ranges just alluded to, though they form an extensive tract of country in the southern portion of the island, from St Abb's Head on the eastern coast, to the Mull of Galloway on the west. This formation corresponds to some of the beds of the Cambrian system, as existing in Wales; and here the first indications of organized fossils appear in some *graphtolites,* discovered in the greywacke slate of Inverleithen.*

---

* Distinct specimens are before us, presented by the discoverer, Mr James Nicol.

The old red sandstone is the next great formation. Traces of this formation are seen diffused over the whole island. It is seen overlying the greywacke in Berwickshire. It skirts the Lammermoors, and extends into Dumfries and Ayr shires. It forms an extensive district in Forfarshire, part of Perth and Stirling shires, and onwards to the western coast. It borders almost uninterruptedly the whole northern and north-western coasts, and occupies many valleys and indentations in the interior of the primary range, while it also rises to the summits of some of the loftiest mountains on the north and north-western coasts. It forms almost the whole surface of the Orkney Islands, and appears in many of the Western Isles. Though it varies in extent and thickness in different localities, it preserves the same general mineral and fossil character throughout; and, viewing its particular position and general diffusion as exhibited in the map, the idea will naturally be suggested that at one period it must have covered nearly the whole extent of Scotland, and that denudation, on a general and extensive scale, has been the cause of its abstraction from the higher primary ridges, and perhaps, too, of its greater accumulation in the declivities, valleys, and coast lines.

The different strata of this sandstone, especially the lower and middle, contain numerous remains of fossil fishes. Some of the upper beds, which have less of the shaley and stratified structure, contain fewer organic remains.

The prevailing inclination of the red sandstone strata is more approaching to horizontal, or, at all events, not so nearly vertical as the older beds on which it lies. There are many exceptions, however, to this general rule.

Carboniferous Strata.—The mountain limestone so largely developed in some parts of England, and forming the basis on which the coal measures rest, is only partially present in Scotland. It exists in beds not exceeding 20 to 40 feet in thickness, in Berwickshire, Mid-Lothian, Fife, Lanarkshire, Ayrshire, and parts of Dumfries-shire. North of the great coal district the true mountain limestone with its characteristic fossils is not found. A secondary limestone, analogous to the English *cornstone*, is found in bands alternating with the upper beds of the old red formation.

The Carboniferous Sandstone, including the coal measures, occupies a well defined tract of country, extending from the Frith of Forth, on the east, to the estuary of the Clyde and the Ayrshire shore on the west. The exact boundaries will at once be seen by a reference to the map. On the south, a line drawn from near the town of Haddington in East-Lothian, extending along the base of the Lammermoors, passing through the upper part of Lanarkshire, and terminating at Turnberry Castle in Ayrshire, will bound this formation, while on the north, a line from St Andrews, on the east coast, extending along the southern edge of the Ochil hills, and, passing through Stirlingshire to Dunbarton, will limit its northern extent. With the exception of the southern part of Berwickshire, and of partial and isolated seams of coal in Arran, Sky, and Brora in Sutherlandshire, the formation is nowhere else found in Scotland.

New Red Sandstone.—This formation, occurring above the carboniferous sandstone in England, is found covering a portion of the county of Dumfries, and is partially seen in some of the Western Islands.

Lias, Oolite, Green-sand, Chalk.—Beds of lias limestone are found of considerable thickness at Cromarty, and in Mull, Staffa, &c. Traces of oolite are also visible in those islands, at Brora in Sutherlandshire, and near Elgin in Morayshire. Chalk nodules apparently *in situ,* or drifted from some neighbouring locality, have also been found near Banff, and a fresh water formation with organic remains, analogous to those of the Wealden in England, exists at Linksfield near Elgin.

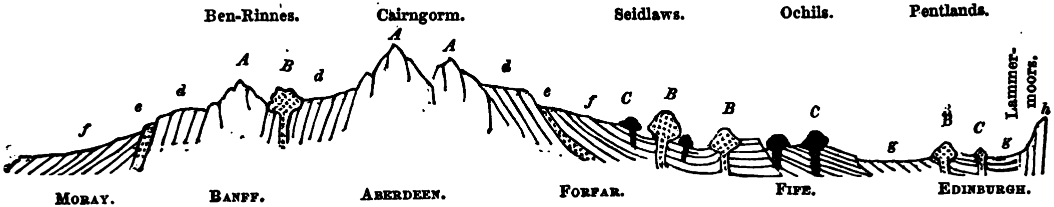
On the whole, however, a remarkable feature of the Geology of Scotland, as compared with England, is the great prevalence of the older strata, and the partial occurrence of the lias, oolite, and chalk, so largely developed in the south of England. Among the older strata, too, the Silurian rocks, intermediate between the Cambrian schists and the old red sandstone of England, appear to be almost awanting in Scotland.

The Igneous formations are *granite* and *syenite*, which are abundant in the middle range of the Grampians, which appear not unfrequently in Sutherlandshire and Ross-shire, and partially in the shires of Argyle, Dumfries, and Galloway.

Porphyry.—This rock, in its varied forms and different ages, is seen penetrating the primary schistose, and the secondary arenaceous formations in many districts. In the primary range it is every where present. It pervades the greywacke range in Galloway, Dumfries, and Peebles shires, and is also present in some of the old red sandstone districts, as well as the carboniferous strata.

Trap Rocks.—These are abundant chiefly where the secondary strata prevail, which strata they both penetrate and overlie. They are seen in a particular class of the Western Islands, and are largely extended through the coal districts. They are more sparingly developed in the middle and northern primary ranges, although their elevating agency is there also frequently indicated, and trap dykes and veins are in several situations visible.

SECTION ACROSS THE GRAMPIANS, FROM MID-LOTHIAN TO MORAYSHIRE.



A, *A*, *A*, Granitic summits of the Grampians; *B*, *B*, Porphyritic mountains of ditto; *C*, *C*, *C*, Trap hills; *d*, *d*, *d*, Primary Schists; *e*, *e*, Red Sandstone conglomerate; *f*, *f*, old Red Sandstone; *g*, Carboniferous Sandstone; *h*, Greywacke of Lammermoors.

The preceding section of the middle portion of Scotland, forming a line from the Lammermoor hills, immediately south of Edinburgh, intersecting the Grampian mountains, and terminating at Elgin, will exhibit the strata on each side of the Grampian range, and their relative correspondence to each other.

A, A, A, Granitic summits of the Grampians; *B, B,* Porphyritic mountains of ditto; *C, C, C,* Trap hills.

d, d, d, are the successive primary and nearly vertical strata of gneiss, mica, chlorite, and clay schists. The correspondence of these strata on the southern and northern sides of the Grampians is very evident. A band of chlorite and clay schist, commencing at the southern extremity of the strata near Stonehaven, traverses the whole country in an almost continuous line to the western coast, where roofing-slates are extensively quarried.

On the north the continuity of the strata is interrupted, but clay-slate is abundant in the Foudlin hills, and talcose and chloritic slate to the westward. After these strata the old red sandstone succeeds in an unconformable position, commencing with the lowermost conglomerate beds, *e, e,* which are seen on both sides, and continuing with the other beds, *f, f,* of this formation in a strikingly regular manner. The carboniferous strata, *g,* which succeed on the southern section of the Grampian range, are awanting on the northern. A larger development of the upper red sandstone beds, and a highly bituminous shaley sandstone in Caithness, may, perhaps, in the present state of our knowledge of facts, be put down as equivalents to the coal measures of the south.

The extensive greywacke formation, in the south, too, seen cropping out from below the sandstone at *h*, is also deficient in the north. No traces of lias, oolite, or any other formation newer than the old red sandstone, are visible in the southern division, while in the north partial indications of them are still visible in the original positions, which even the most violent denudations have not been able totally to obliterate.

GEOLOGY OF THE COUNTIES.

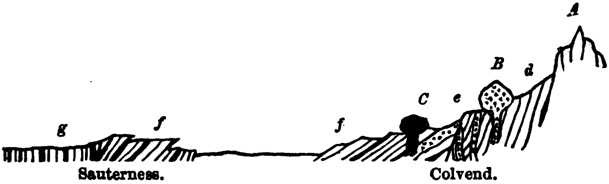
GREYWACKE DISTRICT.

This district includes the southern portion of Scotland, commencing with Wigtonshire, and terminating with Berwickshire on the east. It consists chiefly of greywacke conglomerate, with slates, analogous to the upper beds of the Cambrian system of Wales, of old red sandstone, and mountain limestone, with granite, porphyries, and greenstone.

WIGTON AND KIRKCUDBRIGHT SHIRES.—The counties of Wigton and Kirkcudbright belong to this greywacke district. The surface of these counties is extremely irregular, consisting of a series of elevations and depressions, with no large valleys or very elevated mountains. This surface consists of greywacke schist, greywacke conglomerate, and, in some situations, patches of sandstone conglomerate and grit belonging to the old red formation. A mass of granite intersects New Galloway, and a similar mass stretches from the sea coast, near the burgh of Kirkcudbright, south and south-westward, to form the Criffle range. Feldspar porphyry also abounds in various localities, and the intrusion of this igneous rock seems to be the cause of the great disturbance of the undulated surface.

At Port Mary on the coast, a few miles south of Kirkcudbright, a greyish sandstone, with layers of shale and conglomerate, are seen to rest unconformably on the greywacke. This sandstone continues to skirt the coast, and evidently belongs to the old red formation. At Colvend is exhibited the following succession of strata, onwards along the coast to Sauterness.

SECTION FROM COLVEND TO SAUTERNESS.



A, granite—*B*, porphyry—*C*, trap rocks—*d*, gneiss, dipping nearly vertically with numerous veins of granite and porphyry interposed. *e*, greywacke conglomerate, coarse greyish sandstone, with bands of shale and impure limestone. *f*, a yellowish sandstone.

At Sauterness the grey sandstone, *f*, again appears with minute seams of shale and coal, *g*, and bands of limestone containing encrinites, producti, corralines, &c. The strata here has suffered great displacement; in some situations it dips at a gentle angle to the south, in others it is vertical, and curved, and contorted. The bands of limestone, which are of considerable thickness here, the bituminous shale and slight indications of coal, would point out this as the lowermost strata of the carboniferous formation. At Portwarren are indications of a seam of copper ore, which at one time was wrought, though not to any extent, or much advantage. About half-way between the granitic range of the Criffle and the coast, trap rocks are seen together with porphyritic rocks, as indicated in the above section; here, also, a hard reddish coloured sandstone is visible in several positions, as at Airdrie.

The aspect of the country also undergoes a marked change in this middle and coast district. In the line of the Criffle range it has all the barren appearance of an alpine district, a bare quartzose soil, and scanty vegetation. South of this range, however, and where the trap and porphyry rocks have elevated the sandstone and secondary strata, there is all the appearance of a fertile soil, with trees and luxuriant vegetation.

The northern extremities of these counties are bordered by the old red sandstone formation, and the coal measures of Ayrshire.

Dumfries-shire.—The northern part of Dumfries-shire is elevated, hilly, and composed of greywacke, slate, and conglomerate, with patches of old red sandstone. Greenstone and feldspar porphyry are the igneous rocks which have elevated and undulated this upper district. The lower part of the county along the valley of the Nith is extremely fertile and well wooded. On the banks of the Nith, from Thornhill to Closeburn, the old red sandstone is visible. Above this is an extensive bed of mountain limestone, with its characteristic fossils. Here the orthoceratite is found in abundance, of a most gigantic size. This limestone is extensively quarried and burnt in kilns, where it forms a very pure lime. Another bed above this is said to contain a portion of magnesia, and is reckoned unfit for general purposes of utility.

At Closeburn the old red sandstone disappears from the surface, and is succeeded by a soft, friable, gritty, and deep red sandstone, lying above the limestone.

A section of the basin of Closeburn, according to Mr C. Menteith, exhibits, 1. Deluvium; 2. New red sandstone; 3. Grey and white sandstone; 4. Carboniferous limestone; 5. Greywacke rocks. We quote this gentleman's account of this locality.

"The Nith, after a rugged course of more than five miles, through a pent-up rocky channel in the greywacke rocks, enters the basin of Closeburn, which is completely girdled round by greywacke hills. Of these, the Lowders are the most pleasing. The interior of the basin of Thornhill is covered with rocks of the secondary formation. These are *sandstones* of different varieties and *carboniferous limestone.* The most abundant rock is sandstone. Of it there are three varieties, the RED, WHITE, and GREY. The *red* appears in all its characters to be the *new red sandstone.* It is by far the most abundant. It varies much in its texture, being sometimes hard, but oftener soft and friable. It covers over all the other strata of the basin, but is entirely confined to the east side of the Nith. One of the best examples of the appearance of its varied structure, and the irregularity of its dip, may be seen at Gateley Bridge quarry, on the Cample, where this red sandstone exhibits its beds lying in all manner of directions, horizontal, upright, and variously inclined. In this quarry, roofing-flags are raised and are carried to a great distance. At Crigup Linn, the finest section of new red sandstone, being 100 feet thick, is exhibited. It is there seen covering the other strata of the basin, which may be observed rising from underneath it. In this romantic dell, the most unjustly and cruelly persecuted Covenanters found a secure retreat from their implacable enemies. And the pen of the inimitable Sir Walter

Scott has given this Linn a classical interest, by having, in his tale of Old Mortality, made the Crigup Linn the hiding-place of the daring Balfour of Burleigh.

"The *white and grey sandstones*, which underlie the new red sandstone, are not found in any considerable quantity. The best quarry for these two varieties is the *King's Quarry*, not far from Carron Bridge. They are both of a hard compact texture, well fitted to resist the action of the weather. A very good section of these two varieties of sandstone is to be seen above Drumlanrig Bridge, on the east bank of the Nith.

"The *carboniferous limestone* is found only at the south end of the basin of Thornhill, on both sides of the Nith, as at Closeburn and Barjarg, but at the latter in much less quantity. Organic remains occur in the limestone at Closeburn. Among which are found some spiral shells, producti, corals, and orthoceratites.

"Not far from the Gateley Bridge new red sandstone quarry, a mile above it, on the banks of the Cample, *basalt* in pentagonal columns occurs. It appears to form a narrow ridge or dyke, traceable from Morton Mainshill, on the north-east of this spot, and it seems to take the direction of the Linburn hill on the south-east. Thin beds of ironstone in the greywacke are met in different places.

"In this basin there are found frequently, in many places, large BOULDERS OF GRANITE, exceeding, in some instances, a ton in weight. The granite formation of Ayrshire, from which they appear to have been detached, is many miles distant."

The upper red sandstone here evidently appears to be a continuation of the same new red sandstone of the opposite coast of England. In this sandstone no organic remains have yet been discerned, but traces of the footmarks of several reptiles have been found distinctly marked on slabs of the sandstone, procured from the quarries at Corncockle Muir, and the craigs near Dumfries.*

This red sandstone is distinct in mineral character from the old red sandstone of Thornhill, as well as from the grey sandstone and conglomerate already described as fringing the coast line of Galloway. Its position also above the mountain limestone points it out as a distinct formation from the old red sandstone. It possesses the gritty, moist, friable, close-grained, and ochrey colour, peculiar to the red sandstone of the north and west of England.

Above this red sandstone, and unconformable to its strata, rests a mass of conglomerate, consisting of a base of red sandstone, with masses of trap rocks, greywacke, and slate imbedded. The following section exhibits the position of the strata in the immediate vicinity of the town of Dumfries.

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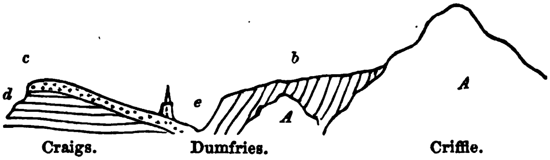
* Described by Dr Duncan, Ruthwell, and figured in Dr Buckland's Geology.



A, granite of Criffle range; *b*, gneiss and mica-slate; *c*, conglomerate rising from the quay of Dumfries; *d*, sandstone of Craigs Quarry.

At the farm of Sherrington, half-way between the town of Dumfries and Caerlavrock Castle, a well was sunk some years ago, when the following strata were bored through; sandstone conglomerate; red sandstone; a yellow sandstone. This yellow sandstone is also partially seen in a ditch at the base of the elevated land where the well was dug. It most probably is identical with the strata seen on the opposite point of the Nith, as already described at Sauterness. At Kelhead, in the parish of Ruthwell, the mountain limestone appears; it is 30 feet thick, of a reddish hue, and contains encrinites, orthoceratites, productæ, and some molluscous testaceæ.

The Lochar Moss is an extensive formation of peat in the vicinity of the town of Dumfries. It is raised only a few feet above the sea level, and there are sufficient indications to show that at no very remote era the sea occupied the whole of this position. Extensive morasses and flat grounds are also to be seen on the Galloway side of the Nith, some of which are in process of being reclaimed from the sea; and, indeed, the whole might be converted into excellent soil, which would in a short time repay the capital necessary for their improvement. At Leadhills, in the upper and northern part of the county, a mine of lead, in the greywacke strata, has been wrought advantageously for several centuries.

The new red sandstone extends into Annandale, until it joins the same formation in England. At Langholm the mountain limestone of the north of England rests on the old red sandstone, and at Cannoby a seam of coal 5 feet 10 inches in thickness is wrought to advantage.

Along the course of the river Annan, the new red sandstone continues to be visible as far as Jardinehall, till at last it is lost in the mountainous greywacke country which succeeds. We here avail ourselves of Mr Menteith's account of these basins:—

"ANNANDALE may be divided into the upper and lower basins.

"The *upper* is separated from the lower basin by a narrow ridge of basaltic amygdaloid rocks, which runs across the river Annan at the manse of St Mungo, thereby uniting the Tinwald greywacke ridge of hills with those on the eastern bank of that river; and this rock may be traced skirting the greywacke mountains from Burnswark to Langholm.

This rock seems to cut off the new red sandstone of the upper and lower basins of the Annan.

"The greywacke mountains which shut in this upper basin of the Annan are lofty, and to the north present a bold picturesque outline, but not so romantically beautiful as the Lowder range of hills of the basin of Closeburn.

"The central parts of this upper basin of the Annan is filled with the *new red sandstone.* This red sandstone is well fitted, from its compact texture, for all kinds of building.

"At Corncockle Muir new red sandstone quarry, which is between the Annan and the Kinnel, the impressions of the land tortoise are observable upon the different beds of this rock.* We have observed the same interesting occurrence at Craigs new red sandstone quarry, in the basin of Dumfries. These fossil animal impressions seem peculiar to the new red sandstone formation. They occur in this formation of rock in Saxony, at Hessberg. We have not as yet found any *white or grey sandstone* any where in this upper basin of the Annan; neither limestone nor ores of any kind have hitherto been met with.

"A mile from Moffat is a *sulphuretted hydrogen*

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* Some impressions which we saw here, and in the museum of Sir W. Jardine, rather appeared to be those of some Lacertine reptile, and not unlike the Lizard footmarks on some of the Liverpool sandstone slabs.

spring, issuing from a greywacke rock, containing iron pyrites, and passing through a peat bog, where it is probably still more impregnated with sulphur. About five miles from Moffat is *Hartfell Spa*, which is a *strong chalybeate*. It issues from a rock of *alum slate* on the side of the mountain of Hartfell.

"The perpendicular section of the upper basin of the Annan is the same with that of the basin of Dumfries.

"1. Soil, with various alluvial matters. 2. New red sandstone. 3. Greywacke rocks.

"The lower basin of the Annan commences to the south of the manse of St Mungo, and expands itself a considerable way towards the Solway Frith; on the west it unites itself to the basin of Dumfries, and to the east to the lower basin of the Esk.

"The sandstone which prevails is the *new red*, which appears to overlay all the other strata. At the Cove Quarry, on the banks of the Kirtle, the light ochrey yellow-coloured sandstone bursts up from underneath the new red sandstone. It is hereabouts, and upon the estate of Springkell, where this ochrey yellow sandstone abounds, that there is any prospect of finding coal. At Linbridge Ford, on the Kirtle, in the year 1795, in boring for coal at 140 feet in depth, a four inch seam of this mineral was discovered. Though coal be found, we are very doubtful if there be beds of sufficient thickness to repay the expense of working it; and, from the late attempts that have been undertaken in this quarter, the prospects of finding a profitable bed of coal are very distant. *Clay ironstone* is interstratified near Ecclefechan, with beds of reddish-brown slate clay. The beds of ironstone are from three inches to a foot in thickness.

"Besides Kelhead already mentioned, the carboniferous limestone abounds in various other places, as at Brownmuir, Blackrig, Cauldron Linns, Highmuir, on the eastern bank of the Annan. The other limestone quarries of Annandale are equally rich in the same organic remains.

"The section of the lower basin of the Annan is the same as that of the lower Esk.

"1. Soil, containing different alluvial matters. 2. New red sandstone. 3. A yellowish sandstone. 4. Coal—metals. We are told that in boring upon the Springkell estate, a thin bed of coal was found. 5. Carboniferous limestone. 6. Greywacke rocks.

"BASIN OF THE ESK.—The river Esk, in its course from its source to the Solway Frith, flows through two basins, an upper and a lower. It is, however, difficult to distinguish the lower basin of the Esk from that of the Annan. They run so much into one another, that a better division of this lower district of Dumfries-shire would be to consider the two as one large basin. The upper basin contains neither coal, lime, nor sandstone, throughout its whole extent, the prevailing rock being greywacke. In the hills around the manse of Eskdalemuir, the volcanic or igneous rocks abound. And among those most interesting to the mineralogist, *pitchstone* may be named. At Glendinning the greywacke contains *grey antimony glance,* or sulphuret of antimony. In the same neighbourhood, among the mountains, there are traces of galena, or sulphuret of lead. And there can be little doubt, where the rocks of the greywacke are hard and compact, lead may yet be found in quantity.

"Lower Basin of the Esk.—Below Langholm, the basin of the Esk expands, and to the west unites itself with the lower basin of the Annan, which may be called the lower basin of the Esk.

"This basin contains uppermost of them all the new red sandstone—under it the coal formation series of strata—and the carboniferous limestone underlaying the coal stratification. On the Byreburn, near Langholm, coal is worked, though no seam exceeding three feet has been discovered. The coal formation at Byreburn is the north-eastern outcrop of the Cumberland coal contained in the basin of the Eden. The greyish black beds of slate clay, which alternate with the seams of coal, contain globular masses of clay ironstone.

"From Langholm, in the direction of Ecclefechan and Brownmuir, *carboniferous limestone* is found in all that range; in which are met with the same organic fossil remains as in the carboniferous limestone of Kelhead and Closeburn; and beyond, to the north of this line, the greywacke.

"PERPENDICULAR SECTION OF THE LOWER BASIN OF THE ESK EXHIBITS—1. Soil, containing alluvial matters. 2. New red sandstone. 3. Yellow sandstone. 4. Coal, found at Byreburn. 5. Carboniferous limestone. 6. Greywacke rocks."

LANARK, PEEBLES, AND SELKIRK SHIRES.—Proceeding from Dumfries-shire into Lanark, Peebles, and Selkirk shires, the land gradually mounts to higher elevations, until, about the centre of Peebles-shire, it attains its maximum. This elevation is attained more by a general rising of the whole surface of country, than by any very high mountains. Hartfell is said to be 3000 feet above the sea level, but it owes much of its elevation to the ground below its actual base. Tinto, in Lanarkshire, is 2260 feet.

Here, too, as indicating the highest point of land, the commencements of both the rivers Tweed and Clyde are seen to take their rise in two small streams, which run for some time within a few miles distance of each other, till at last they both take directly opposite courses; the Tweed winding south-eastward through the valleys of Selkirk and Roxburgh shires, and receiving the waters of numerous tributary streams from the surrounding high lands, while the Clyde rushes down the abrupt declivities of Lanarkshire.

The same greywacke slate forms the prevailing strata. Occasionally the old red sandstone is seen in the valleys and deep gorges of the hills. It is thus found in the valley of Moffat, and extends along the borders of Lanarkshire, and the north-western portion of Peebles-shire, where it is intersected by a range of porphyritic rocks, of which Tinto hill forms the most conspicuous. The composition of this hill is a claystone porphyry, similar to that found in the Pentland range.

A harder, and probably an older porphyry, similar to that found in Galloway and Dumfries shires, is also frequently seen in contact with the greywacke, as also greenstone and basaltic rocks. The appearance of this whole district presents a succession of round, smooth, grass-covered hills, with a very moderate elevation, and few bold or striking features. The intervening valleys are numerous in proportion, of narrow winding forms, and generally watered by a rivulet.

Roxburgh and Berwick Shires.—A considerable part of Roxburghshire is composed of old red sandstone. The central valley consists in a great measure of this rock, elevated occasionally from its general level by trap rocks. It presents a fertile and beautiful country. On the south it is bounded by the mountainous range of the Cheviots, composed of trap rocks, on the east the mountain limestone of the English strata prevails, on which is superincumbent on carboniferous sandstone, and occasional seams of coal. Near Melrose, the old red sandstone is seen to terminate on the edge of the greywacke hills. Here is also a trap tuff conglomerate, and the famous Eilden Hills are formed of greenstone.

Berwickshire is bounded on the north by the Lammermoor range of mountains, the highest portions of which attain an altitude of 1200 to 1700 feet. From the base the county slopes gradually towards the Tweed.

The northern district consists of greywacke, the strata of which are generally in a vertical position. It is composed of an aluminous sandstone of a greenish-olive, or sometimes reddish-brown colour, generally of a softer and less compact slaty nature than the greywacke to the westward. Trap rocks traverse the whole range, and at those parts where they come in contact with the slaty strata, the latter is so much indurated as not to be readily distinguished from greenstone.

To the greywacke strata the old red sandstone succeeds in an unconformable manner, the strata assuming more of a horizontal direction. The lower beds consist of a coarse conglomerate, the upper of a friable deep red sandstone. At Dunse scales of the *holoptychus* have lately been found in the upper beds,* thus identifying them with the Clashbinnie and other red sandstones of the northern counties.

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* Millar.

The sandstone beds, as seen in section on the Tweed, vary in thickness from 30 to 50 and 100 feet and upwards.* Immediately succeeding to the old red sandstone is the carboniferous series; the lowermost bed of which, the mountain limestone, is seen in considerable thickness at the pier of Berwick, and extending eastward along the shore. This limestone is full of one of its most characteristic fossils, the *encrinites moniliformis.* Superincumbent on this limestone are beds of a white compact sandstone, similar to that of Mid-Lothian, interspersed with bands of aluminous shale, and containing profusion of vegetable remains of *lepidodendrons, calamites, stigmariæ,* and *coniferæ.* Several coal seams are also wrought on the Tweed, in the immediate vicinity of Berwick. This coal differs both from that of the Great Scotch Field and from the Newcastle coal, and is probably intermediate between those two.

The carboniferous strata rise to north-west, and appear to pass gradually into the old red sandstone formation below.

Three or four seams of coal are also to be met with on the north side of the Lammermoors.

Superior to the carboniferous sandstone, several patches of a sandstone, conjectured to be the new red, are also visible, scattered over the southern part of the county. Trap rocks, consisting of greenstone, basalt, and claystone porphyry, intersect the whole district. Porphyry sienite, and also granite,* are found in the Lammermoor range.

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* Milne, Prize Essays of Highland Society.

HADDINGTONSHIRE.—The old red sandstone constitutes about two-thirds of the eastern part of this county, the rest belongs to the carboniferous series. The county is generally level, and extremely fertile, having a deep covering of rich alluvial mould. The old red sandstone forms a bold rocky shore in the neighbourhood of Dunbar, and extends westward along the shores of the Forth till it meets with and sinks below the coal measures.

Berwick Law and *Traprain* are two conspicuous conical hills formed of clinkstone.

The Bass Rock is also here a magnificent object, forming an isolated island amid the waters of the Frith. It is from 500 to 600 feet in height, with precipitous sides, assuming somewhat of a columnar form and a conical summit, which becomes the annual haunt of a colony of gannets or Solan geese.

The rock is a compact clinkstone, and similar to that of Blackford Hill near Edinburgh.

There is a fissure or cave on the eastern side, but the rest of this huge mass is solid and compact. A spring of water is found near the summit.

The Isle of May, another interesting object, lies at the distance of a few miles in the centre of the Frith. It is entirely composed of a compact greenstone, the weathering of which has produced a considerable depth of soil, which admits of tillage.

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* Milne.

THE GREAT SCOTTISH COAL FIELD.—The boundaries of the carboniferous strata have already been pointed out, and a glance at the map will at once indicate the well defined lines by which this field is limited. It will be seen that it occupies a space extending from the east to the west coast of the island, and almost forms an exact parallelogram. At both these extremities it is terminated by the ocean, but on the north and south sides it is hemmed in by two elevated ridges of the older strata. At both these places it rests and terminates on the old red sandstone, which latter, again, reposes in the north on the great primary range of the Grampians, and in the south on the greywacke range of the Lammermoor hills. It thus becomes apparent, that at the period when the coal measures were deposited, this space must have formed a great hollow between the two older elevated ranges, and that it owes its subsequent elevation to the more recent intrusion of the trap rocks, by which it is throughout pervaded.

The coal-field includes the counties of Edinburgh, Haddington, Linlithgow, Lanark, Ayr, Renfrew, Dunbarton, Stirling, and Fife.

The only deviation from a nearly continuous and rectilinear outline is the portion of coal strata at Sanquhar, which juts like a peninsula into Dumfries-shire.

The general character of this great coal bed is nearly uniform throughout. It rests on a band of mountain limestone, in no situation exceeding 40 feet in thickness. This limestone is of marine origin, and contains abundant remains of encrinites, testaceous molluscæ, and zoophytic corals. Sometimes several bands of this limestone alternate with the lowest beds of the coal measures, and in some localities beds of fresh-water limestone, with peculiar fossils, are found.

Above the limestone bed lies the carboniferous sandstone. Its general character is that of a compact fine-grained sandstone, white, yellowish, or reddish. In some situations, as in the vicinity of Glasgow, it is of a reddish-blue, coarse-grained structure. In others, as at Killalo in Fife, it is nearly pure white, with a calcareous admixture. Beds of conglomerate and shale alternate with the more compact sandstone, and in various localities seams of coal alternate to the number of thirty and upwards. The coal seams almost invariably rest on a band of fire clay or ironstone. The character of the coal varies with the position of the seams In some it is largely charged with bitumen and carburetted hydrogen, in others it is greatly mixed with earthy and argillaceous matter, rendering it a dull burning coal.

The depth of this formation varies in the various localities, nor has the actual general depth been yet ascertained. In some bores it has amounted to 2000 or 3000 feet. The coal measures generally assume a basin shape, and are thus deeper in the middle than at the extremities.

The shale sandstone and coal seams teem with vegetable remains, a few of the most common of which are here enumerated.

The *Stigmaria ficoides* is one of the most common plants in the coal measures, and, from all we can learn of its structure, perhaps one of the most singular. It was most probably dicotlyledonous, and nearest allied to the recent families of euphorbiaceæ, cactæ, and asclepiadeæ. Contrary to the usual erect position of plants, it seems to have grown horizontally, spreading out its flat leaves near the muddy soil. The nature of its stem is unknown; but the central junction of its leaves forms a knot of three feet in diameter. The leaves appear to have been cylindrical. They are marked with numerous raised round protuberances or dots, from whence the leaflets sprung.

Five or six species have been found in the coal strata.

The *Calamites* have jointed stems, regularly and closely furrowed longitudinally, These are hollow, and divided internally at the joints by a transverse diaphragm, and covered with a thick bark.

Several species have been discovered.

The *Filices* or ferns are numerous.

In the *Sphenopteris,* the leaves are bitripinnated, the leaflets contracted at the base, and not adherent to the rachis. They are lobed, the lower lobes largest, diverging, and somewhat palmate.

Twenty-eight species in coal formation.

Neuropteris. Leaves bipinnate, and rarely pinnate. Leaflets somewhat cordate at the base.

Twenty-four species ascertained.

Pecopteris. Leaf once, twice, and thrice pinnate.

Schizopteris. Leaf linear plane, without midrib, finely striated.

Lycopodites. Branches pinnated, leaves inserted all round the stem, in two opposite rows, not leaving clear and well-defined scars.

Ten species in coal-fields.

Lepidodendron. The stems are dichotomous, covered near their extremities by simple linear or lanceolate leaves, inserted upon rhomboidal areolæ. The lower parts of the stems are leafless. The areolæ are larger than broad.

Three species in Edinburgh coal-field.

Lepidodendron—Selajinoides.
——————— *obovatum.*
——————— *Sternbergii.*

Ulodendron. The stem covered with rhomboidal areolæ, which are broader than long. Scars, large, few, and placed one above the other. Circular, composed of broad wedge-shaped scales, radiating from a common centre, and indicating the former presence of organs that were perhaps analogous to the cones of the coniferæ.

Two species in coal-fields.

Lepidophyllum. Stem unknown. Leaves sessile, simple, entire, lanceolate, or linear; single midrib, or three parallel ribs; no veins.

Five species in coal-fields.

Lepidostrobus. Cones ovate or cylindrical, composed of imbricated scales, inserted by a narrow base around a cylindrical woody axis, their points sometimes dilated, and recurved in the form of rhomboidal disks. Seed solitary, oblong; root winged, nearly as long as the scales.

Five species in coal. Three found in Edinburgh district, *L. ornatus, variabilis, comosus.*

Sigillaria. Stem conical, deeply furrowed, not jointed. Scars placed between the furrows, in rows not arranged in a distinctly spiral manner. Smooth, much narrower than the intervals that separate them.

Forty species in coal.

Equisetæ—various species.

Cyperites bicarinatæ.

Algæ—Fuci and various species.

If to this list, chiefly composed of vascular cryptogamic plants, we add the various species of the coniferæ, or pine tribe, including the araucaria, salisburia, &c., we comprehend those vegetables which seem to have composed the great mass of our coal strata.

The coal-field is everywhere intersected by traprocks, consisting of greenstone, claystone, and basalt. The intrusion of these has broken up and displaced the strata in almost every locality, and to these the original low and hollow valley of the whole district must have owed its elevation to the present level. Comparatively few trap dykes come in contact with the coal seams in this country, and to this circumstance is probably owing the absence of the fire damp or carburetted hydrogen so common and so perilous in the English coal-fields. The dip of the coal strata varies much according to the circumstances of the locality. The prevailing dip, however, corresponds with the general inclination of the strata of the district, which is from south-west to north-east.

EDINBURGHSHIRE.—This county is bounded on the north by the Frith of Forth, and on the south by the range of the Lammermoor hills. The eastern half presents a low-lying, gently undulating, and fertile valley, which continues eastward into East-Lothian and Haddington shires. To the west and south-west the county is more elevated, by the range of the Pentland and the Moorfoot hills. The soil here is less fertile, and the appearance of the fields less luxuriant. In the centre of the county there are two valleys, that of the Esk, commencing from the ridge of high ground a few miles south of Arthur's Seat, and bounded on the south by another ridge two miles south of Dalkeith, extending in a line from the Roman Camp to Cousland, and a point mid-way between Musselburgh and Tranent. The second valley of the Tyne lies immediately south of this ridge, and embraces the intervening country to the base of the Lammermoor hills.

The lowest visible strata in this county is the old red sandstone, which crops out at the base of the Lammermoors, and is also seen at Roslin. Traces of a coarse conglomerate and reddish sandstone are also visible in some of the valleys of the Pentlands, on the elevated ridge to the north-eastward of Libberton, and other localities, which, perhaps, also belong to this formation. The next strata in succession is the mountain limestone, which forms the basis of the coal measures. This limestone is seen at Gilmerton, three miles south of Edinburgh. Here it has been quarried from an early period, and shows a depth of thirty-seven feet. It is of a hard compact greyish colour, containing innumerable fragments of the *encrinites moniliformis*, and shells of the *productus*, *spirifer*, &c. Above this compact bed of limestone from ten to fifteen feet of shale and soft clay sandstone rest where the same organic remains are also abundant. The strata here take a sudden dip to the south-eastward, and pass below the coal measures of the valley of the Esk. The escarpment of the strata exposed extends about a quarter of a mile westward, while fragments of the same limestone make their appearance in several places to the eastward. In a direct line south-west lies the Burdiehouse quarry, but we shall at present pass on, and describe the limestone on the summit of the elevated ridge south of Dalkeith, called the Roman Camp, which is evidently a continuation of that of Gilmerton, after it has passed below the coal strata. There are two large limestone quarries here, one on the north, and the other on the south summit of the hill. Both are identical in their characters, consisting of a lower bed of hard compact blue limestone without much appearance of stratification, while above lies in regularly stratified succession a greyish-blue argillaceous limestone, called blaes, and shale and loose clay. This upper stratified mass contains the remains of shells in greater abundance than the lower. An interesting appearance presents itself in the north quarry, of an upper bed of sandstone and shale lying unconformably to the limestone below, which seems evidently to have been deposited after the latter had been raised up, fractured, and very much disturbed.

At Crichton, about half a mile south-eastward of this position, the limestone again makes its appearance at the foot of the Roman Camp Hill. Here the lower rock appears with nearly a horizontal position of the stratification, with many cavities and oblong undulations, worn smooth and polished, evidently by the former action of the waters of the sea, just as we now see similar rocks within water-mark acted upon by the surrounding ocean. Immediately above this mass of rock a well marked line of shale commences ; this is followed by a stratum of blaes, then another layer of shale, and so on till we come to the top. Above lies the clay deluvium common to the whole district, which seems to have been at an early period washed through the numerous fissures, for it pervades the blaes and limestone throughout.

The same limestone crops out in several places to the eastward along the elevated ridge which has been just described, and a quarry is extensively wrought at Cousland.*

Burdiehouse† *Quarry* lies near the village of that name, three miles south-west of Edinburgh, and within half a mile of the Gilmerton marine limestone, lying a little north of west of the general line of direction of that strata.

Public attention was first called to this locality by Dr Hibbert in 1833.‡

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* Rhind's Geology of Environs of Edinburgh, 2d Edition, p. 28, 29.

† A popular corruption for *Bourdeaux-House*, where some of the suite of Mary Queen of Scots resided, when she was at Craigmillar Castle.

‡ Edinburgh Philosophical Transactions, 1834.

The bed of limestone is here twenty-seven feet thick, of a dark blue colour, disposed in layers of a slaty nature; the lower beds being harder, more compact, and of a lighter colour than the upper. Above is a bed of shale of a highly bituminous character. The limestone dips to the south-east at an angle of 25°. Two faults, consisting of an impure mixed argillaceous limestone, interrupt the continuity of the strata to the east. The exact position of this bed, in relation to the contiguous strata, cannot with precise accuracy be ascertained. It is, however, evidently below the coal measures, as is seen in a natural section on the road leading to Loanhead. The coal shafts at Loanhead, too, in penetrating through these measures, do not encounter this particular bed, although there is between the coal seams a bed of marine limestone of some thickness. From the relative dips of the Burdiehouse and Gilmerton limestones, the former would appear as if below the latter, but as they may each owe their present elevation to separate intrusions of igneous rocks from below, it remains uncertain what is their actual relative position. It may be probable that the Burdiehouse limestone is only a partial and local deposition, and that it does not extend southward below the whole coal-field. Deep sections of the Esk basin, including the Gilmerton strata, afford no indications of the Burdiehouse limestone, nor are any traces of it to be found at the Roman Camp out crops of strata. The Burdiehouse limestone is rich in organic remains, both of vegetables and animals; indeed, to the presence of these it owes its dark bituminous appearance. The vegetable remains found in greatest abundance are those common to the coal formation, with the exception of the *Stigmaria ficoides*, traces of which are here rare, although abundant in the superincumbent strata. The *Lepidostrobus ornatus* and *variabilis* are common. *Lepidostrobus comosus* more rare.

Lipidodendron, several species; *Lepidophylla* very common. Several species of *sphenopteris*, the *affinis*, *bifida*, *linearis*, &c.

The impressions of these plants on the limestone slabs are exceedingly perfect and beautiful. Even their most delicate traces are accurately preserved, indicating that the originals must have been deposited in a placid muddy bottom, which has been by some means suddenly consolidated before maceration of the plants could have taken place. These impressions of plants are chiefly found in slabs immediately above the more solid lower mass, and between it and the bituminous shale.

The ancient remains consist of fishes chiefly of the following *genera* of Agassiz:

Gyracanthus, *Pygopterus*, *Paleoniscus*, *Eurynotus*, *Amblypterus*, *Acanthodes*, *Megalychthes*, *Holoptychus*.

The huge bones, teeth, and scales of the latter two sauroid fishes have been found in this deposit, and thus assimilate it in date to the upper beds of the old red sandstone, where the holoptychus existed in great numbers. There are besides embedded in the limestone innumerable shells of a *cypris, daphnoidea, unio,* and a minute *nautilus. Coprolites* of various sizes are also strewed through the whole rock.

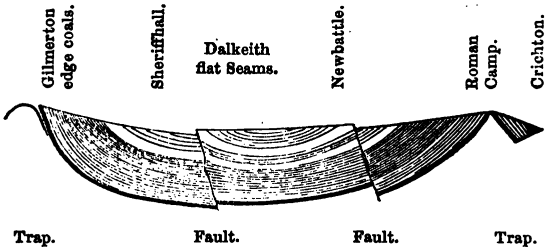
Carboniferous Sandstone. This sandstone covers the greater part of the surface of the country immediately below the soil and subsoil. It is generally of a compact fine-grained structure, and of a whitish or yellowish colour. Sometimes it passes into a gritty bed, and into a conglomerate; beds of a reddish or yellowish hue also occur in the formation. It is of varied depth, sometimes forming hollow basins of great thickness, and then thinning off. It is interspersed in many places with bands of shale, and sometimes puts on a slaty structure, as at Hailes Quarry, at other times it is found in immense masses with the lines of stratification more remote, as at Craigleith.

In this latter locality sometimes it bears evidence of having been drifted in its accumulation. At other times the position of the layers indicate a gradual and tranquil deposition. Distinct ripple marks are apparent on many such slabs at the line of their natural separation. At Craigleith the quarry is excavated to the depth of 150 feet. The sandstone is small grained, uniform, hard, and of a whitish or slight yellow colour, and consists of arenaceous quartz, alumina, mica, and a small proportion of lime.

Three large fossil trees have been found in the lower beds of this quarry. They are *coniferæ*, (*araucaria excelsa*,) and of considerable size. In the upper shaly beds of the quarry profusion of the common vegetable fossils exist. At Granton, a similar stone, with the same organic remains, is found, and at Wardie a bituminous shale, containing fishes, fossil plants, and coprolites in abundance.

The sandstone of the Calton Hill exhibits a coarse conglomerate, containing fragments of the primary rocks, and porphyries, and identical with a conglomerate at Slateford, near the base of the Pentlands. This and a reddish sandstone at Salisbury Crags, and in some localities to the westward, belong probably to the lowermost beds of the coal series.

The *coal-field* of Mid-Lothian commences at a line extending from Joppa, on the sea-shore, to Gilmerton and Loanhead, Magbie Hill and Carlops to the westward, and passes southward to the small river Tyne. On the south coast it extends to Tranent. It forms, as already stated, two basins, the position of which will be better understood by the subjoined wood-cut.



The basin of the Esk contains altogether nearly seventy seams of coal, alternating with shale and sandstone. Thirty-two of them only are of any magnitude, and only a portion of them workable. The Tyne basin contains only a few of the lower beds of the series.

The Edmonstone, or Dalkeith flat seams, contain a depth of seventy-eight fathoms of strata, with six seams of coal, the total thickness of which seams amounts to twenty-seven feet. The jewel coal is the lowest seam.

The South Esk beds have a total depth of 387 fathoms, and contain twenty-six seams of coal, the aggregate thickness of which is eighty-two feet. The seam of parrot coal lies lowest. Seven minor seams then succeed, and are followed by the main seam nine feet in thickness.

The seams of coal vary from six inches to nine feet in depth—the average being from two to three feet. The coal occurs at greater intervals near the top, and increases gradually as we descend. There is a remarkable space of 540 feet near the top, where no coals occur. Generally the coal seams are accompanied with several feet of shale, but sometimes they rest upon the sandstone, with a thin layer of fire clay intervening.

At the Roman Camp, the dislocation of the strata has been so great as to elevate the limestone on each side of the hill, and throw the coal seams to the south side in a reverse direction to those on the north. Here the southern boundary of the Edinburgh coal-field terminates.

Although there are numerous slips and dislocations of the Edinburgh field, yet it is rarely traversed by trap dykes; and in no situation is there any evolution of carburetted hydrogen gas in such quantity as to cause explosions, or even annoyance.

The Scotch coal varies much in quality; in general it is a brisk burning coal, blazing with considerable flame and heat, not caking like the English coal, but leaving a white ash, more or less copious, according to its quality.

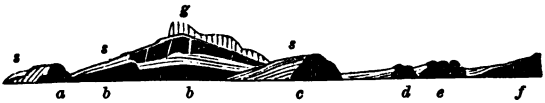
The cannel or parrot coal is procured from the lowest seam in the coal-field on the Marquis of Lothian's grounds, south of Newbattle. About 4000 tons of this coal are annually consumed by the Edinburgh gas works, besides a considerable quantity sent to other towns for a similar purpose. The total quantity of coals sent by the railroad to Edinburgh amounts annually to upwards of 80,000 tons.

Although the consumpt of coals has increased very much within the last century, yet the whole workings, as yet, may be considered only a fraction of the total mass. Mr Bald calculates that, in the estate of Newbattle alone, there are as many coals as would supply the Edinburgh consumpt, about 350,000 tons annually, for 500 years.

The trap rocks of the district extend in a direction from south-west to north-east, they having been the elevating cause of the sandstone strata, have broken it up in all directions, and produced the present form which the surface of the county assumes.

The prevailing trap of the Pentlands is a claystone porphyry, and clinkstone, with amygdaloid, containing jasper, agates, green earth, quartz, and carbonate of lime. Braid and Blackford Hills partake of the same character. Corstorphine Hill and Cramond Island rocks are composed of a syenitic greenstone rock. The Castle Hill is a basaltic greenstone, the Calton Hill a claystone, porphyry, and greenstone. Arthur's Seat is composed of greenstone, greenstone porphyry, and a central mass of basalt.

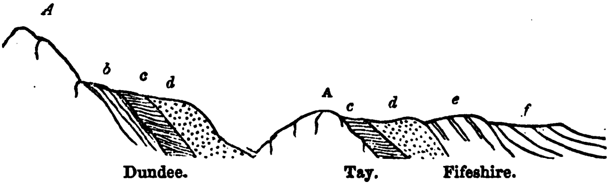
The general form of these hills exhibits a steep precipitous front to the west, with a sloping side to the east, on which repose the elevated sandstone strata, as seen in the following diagram.



a Calton Hill. *b* Salisbury Crags. *c* Castle Hill. *d* Blackford Hill.
e Braid Hill. *f* Pentlands. *g* Arthur's Seat. *s s s* Sandstone.

Linlithgow.—The carboniferous strata extend to the westward into Linlithgowshire, where the mountain limestone crops out in several localities, and where traces of a limestone similar to that of Burdiehouse is also occasionally met with. The valley remains level and fertile for a considerable number of miles, till the elevated range of the Lanarkshire hills intervene, and a bleak hilly tract continues on to the Valley of the Clyde, in Lanarkshire.

Fifeshire.—This county is in the form of a peninsula, bounded on the north and north-east by the Frith of Tay, and on the south by the Frith of Forth. In geological character, it partakes of the strata which adjoin it on the north and south. The line of the small river Eden flowing past Cupar, and discharging its waters into the sea near St Andrews, divides the county into two distinct geological portions. North of this line the strata consist of the old red sandstone, intersected by the trap rocks of the Ochil range. To the south of the Eden the carboniferous strata prevail, with numerous croppings out of coal seams.



The above section will serve to illustrate the succession of the strata. On the left is the old red sandstone formation of Forfarshire, resting on the Seidlaw Hills, and to be afterwards explained. On the right to the south of the Frith of Tay the same strata are repeated. A is the trap rocks which bound the northern portion of Fifeshire; *c* is a grey slaty sandstone, containing faint traces of vegetable remains; *d* is the red sandstone conglomerate, containing scales of the *holoptychus* and other fishes; *e* is a yellow compact sandstone, which occupies the valley of Stratheden, and under* which is found a band, or perhaps bands, of concretionary limestone, or *cornstone.* This limestone is destitute of organic remains; but the yellow sandstone contains scales of the *holoptychus* and other fishes, with very perfect specimens of the *pterichthys.*

The grey sandstone is seen at Wormit Bay, on the shores of the Tay, in contact with the trap rocks. It is of a bluish-grey colour, soft, micaceous, and foliated. Slight indications of culmiferous vegetables are visible, with compressed circular flat patches, not equalling an inch in diameter, and composed of numerous contiguous circular pieces, compared by Dr Fleming to a flattened bramble or raspberry. Above this sandstone lies the carboniferous limestone and coal measures of the southern portion of Fife. The red sandstone *d* is seen at Dairsie, on the north bank of the Eden, dipping to the south-east, and containing the same organic remains as the Clashbinnie limestone in Perthshire. The same sandstone makes its appearance at Birkhill, and on the beach at Balmerino.

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* Mr Anderson, Edinburgh Philosophical Journal, vol. xxiii. and Agricultural Prize Essays, vol. vii.

Between the red sandstone at Dairsie and the yellow sandstone of Drumdryan, a band of cornstone or unfossiliferous limestone occurs. Then follow the yellow sandstone beds *e*, as seen at Drumdryan on the ridge of the hill south of Dairsie. This sandstone is compact, small-grained, homogeneous, and very similar to the yellow sandstone of Morayshire. The Fife sandstone is, however, more fertile in organic remains than the other.

The trap rocks of the north of Fife are of the same character as those of the range of the Ochils, of which, indeed, they are a continuation. They consist of greenstone, basalt, clinkstone, an amygdaloidal greenstone, with agate nodules, and a felspar porphyry of a light reddish hue. This porphyry is seen in contact with the amygdaloid rocks of Wormit Bay; but apparently of a distinct and separate formation.

The *coal measures* commence immediately to the south of the river Eden, and extend along the whole southern part of the county to the shores of the Forth. The mountain limestone, forming the lowest bed of this series, crops out along the northern edge of the coal-fields, at various places. It is extensively quarried at Cults and the village of Ceres, and again makes its appearance in the eastern corner of the county at Pittenweem. This limestone contains the organic remains characteristic of the mountain limestone, as *encrinites, productæ, spiriferæ, turbinoliæ.* Another band of limestone is found higher up in the coal measures; it is of a less pure quality, and the only remains hitherto found in it are numerous minute shells,* probably the *cypris* and other *entomostracæ.* In consequence of the frequent intrusion of trap rock, and consequent breaking up of the strata, the coal seams reach the surface, and are wrought at a great many points in the county—a few of the most important works in which we shall here enumerate. In the northern division, coal is wrought at Ceres, Kettle, Skelpie, Lathocker, and in the east and south coast, at Pittenweem, Elie, Easter and Wester Wemyss, Dysart, Kirkaldy. Innumerable remains of vegetables are found in the coal strata, as also the teeth of fishes, among others those of the *holoptychus* and *megalichthyes*. Trap rocks and dykes every where intersect the county. These rocks become conspicuous in the hills called Largo and Kelly Law. A trap dyke, or vein, penetrates the coal-fields from Largo to Kennoway, and from thence northwards to Markinch, and a dyke of trap tuff traverses the site of the town of Kirkaldy.

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* Mr Landale, Agricultural Essays of Highland Society, vol. v.

At Burntisland, in the trap rocks to the north of the town, is seen a compound vein, consisting of brown crystallized limestone, with greenstone traversing it. At Dunfermline a coal-pit is wrought.

The sandstone of the south coast contains several caves, and some indications of the former action of the waters of the sea, probably at a period when the strata had lower level than at present. The general dip of the strata here is to the eastward.

In Largo Bay are the remains of an ancient submarine forest. These remains rest upon the carboniferous sandstone. The peat is composed of the remains of land and fresh water plants, such as are common in similar deposits of the present day. Along with these appear fragments of trees, particularly the birch, hazel, and alder, as well as nuts of the hazel. The roots of some of the trees occupy their original position, having grown on the surface of the clay, which lies immediately under the peat.

CLACKMANNANSHIRE.—This county forms a continuation of that of Fifeshire, and partakes of the same character. It is bounded on the north by the chain of the Ochils. On the south are the carboniferous strata containing the Clackmannan coal-field. This field forms the north-west boundary of the coal district of Scotland, no series of thick or workable beds of coal being found any where further west and north of the river Forth.* This field is bounded on the north by the Ochils, on the south by the river Forth, which divides the county from Stirlingshire, and on the west by the Carse of Stirling. Bencleuch, the highest of the Ochil hills, is 2400 feet above the sea level; Woodhill, immediately south of this, is about 1800 feet high. In the clinkstone porphyry of the Woodhill, a rich vein of silver was wrought many years ago, and silver extracted to the amount of L.60,000. Along with the silver ore peach blossom coloured cobalt ore was found in abundance. Veins of copper have been wrought to the westward of Blairlogie, and at Airthry, where the vein was found in a rock of dark brown-coloured trap-tuff. Veins of lead have also been wrought to the eastward in the Gloom at Castle Campbell. The coal bed commences at the base of Woodhill, resting upon the old red sandstone, and extends to the coast, a distance of six miles. The field is divided by slips into three portions. The general dip is to the north, except a portion of the south coal-field, which assumes a saddle shape, another portion next the Frith which dips to the south, and the strata near Woodhill, which assume almost a vertical position. The depth of bore through the strata has been made to the extent of 703 feet. This strata consist of sandstone of various textures, shale, bituminous shale, fire clay, and clay ironstone, with nodules. In this there are twenty-four beds of coal, with an aggregate thickness of fifty-nine feet. The seams vary from two inches to nine feet. The underlying limestone has not been reached, but under the mass of greenstone forming the Abbey Craig, near Stirling, are found sandstone, clay slate, and thin beds of limestone. Here, too, the old red sandstone makes its appearance.

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* Mr Bald, Wernerian Transactions, vol. iii.

Above the yellow sandstone lies, in some places, especially at Harvieston, to the west of Westerton Glen, a reddish sandstone, with masses of a red micaceous sandstone embedded, which are of a very hard quality.

Above the coal measures lies a mass of red clay deluvium, or *till*, in some places to the depth of 160 feet. This deluvium contains water-worn fragments of the older rocks, also sharp angular fragments of sandstone, shale, and coal, but no organic remains. Above this is a recent alluvial deposit of considerable depth, also containing oyster and other recent marine shells, as well as bones of the whale and species of the stag, together with the trunks and branches of trees, hazel-nuts, and other vegetables.

STIRLINGSHIRE.—The northern part of this county consists of primary schists. Ben Ledi, attaining the height of 3000 feet, is composed of mica schist and quartz rock.

Then succeeds the old red sandstone, in the middle district, through which flows the rivers Teith and Forth. It is seen at Callendar. The south-eastern portion consists of the carboniferous sandstone of the coal strata. Trap rocks intersect the county, forming, in various situations, bold and picturesque elevations, as at the Castle Hill, Abbey Craig, &c. The greenstone rock on which the castle is built attains a commanding elevation, very similar to that of Edinburgh Castle. Here, too, the junction of the trap and sandstone, as first pointed out by Dr Maculloch, is seen in a very interesting section.

The same formations extend into the adjoining county of Dumbarton, in almost parallel uninterrupted lines, and with very little variations of geological character. At Aberfoil is a quarry of roofing slates. The splendid country of the Trossachs and Loch Katerine is composed of mica and clay schists. Dumbarton rock is an isolated mass of greenstone, connected, however, with the great line of trap rocks which traverses the county in this direction.

LANARK AND RENFREW SHIRES.—Both these are included in the great carboniferous formation. The upper part of Lanarkshire is formed of greywacke. To this succeeds the old red sandstone, while the basin of the Clyde consists of coal measures, with sandstone of a yellowish and dark red or purple colour. Extensive beds of coal and ironstone are wrought in this county.

LANARKSHIRE.—The old red sandstone traverses the county from east to west, and intersects the bed of the Clyde at Lanark. Here it forms cliffs of 400 feet in height, over which the waterfalls of the Clyde thunder their incessant torrents. Its eastern boundary is about Carstairs, near Carnwath, and it extends westward throughout the whole extent of Lesmahago parish. Immediately above this sandstone, and intermediate between it and the carboniferous limestone, are a series of beds of light grey sandstone, chert, and shales.* The same red sandstone crops out in Dumbartonshire, and thus are formed the south and north boundaries of the Lanarkshire coal basin.

This basin consists of alternating beds of limestone, shale, ironstone, sandstone, and coal.

It has been divided into a lower and upper series. The lower series contains three beds of limestone, varying from three to twelve feet in thickness, several bands of valuable ironstone, and fifteen beds of coal.

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* Mr Craig, Prize Essays, Highland Society, vol. vi.

These beds crop out in the southern district of the coal-field, immediately following the old red sandstone. They again appear to the north of Glasgow, while the upper beds occupy the centre of the coal-field. These upper beds contain only a few bands of limestone; but are composed of sandstone, shale, and ironstone, and thirty-four seams of coal. The fossil remains of the lower beds are all of marine origin, while in the upper are found fresh-water shells of the genus *Unio* in abundance. The thickness of this bed is calculated at 1320 feet. It abounds in the usual fossil plants of the coal series; and in the dorsal rays, scales, and teeth of *ganoid* fishes.

There are nine workable coal seams, about twenty-five of which do not exceed fourteen inches.

The workable seams are—

1. The upper coal; a thin seam that thickens out in only one or two instances to be workable. In Millfauld's pit, Coatbridge, it is the fourth seam found, and is two feet three inches thick.

2. The Ell coal. At Mossdale, or upper coal of the Glasgow field, it is three to four feet in thickness. It is wrought at Chapelhall and Airdrie. At Quarter, near Hamilton, Dalserf, Motherwell, and Coltness, it is from six to fourteen feet thick.

3. The Pyot Shaw coal of the Monkland, and the

rough Ell coal of the Govan coaleries, from three to five feet thick.

4. The Main coal, sometimes connected with the Pyot Shaw, forming a thickness of nine feet. This occurs at Drumpellier, Chapelhall, Newarkhill, and Ballochine.

5. The Hump coal, about Glasgow, attains a thickness of about two and a half feet, but is seldom wrought.

6. The Splint coal. This is reckoned the best coal. It is from two to four feet thick near Glasgow; at Larkhill, five feet. Its distance from the Hump coal is about twenty-four feet, and from the Main coal sixty feet.

7. The Virtue-well coal, or Shotts Laigh coal, two and a half to four feet thick.

8. The Killongan coal is very bituminous; it is from two to four feet thick, and is wrought near Larkhall.

9. Drumgray coal, about eighteen inches thick.

The principal ironstones of the upper series are—

1. Upper Black Band, Palace Craig, Old Monkland.

2. Mushet's Black Band, sixteen fathoms below the splint coal, is from fourteen to eighteen inches thick, and occupies an area of nine or ten square miles, in the neighbourhood of Airdrie, supplying the iron-works in the vicinity.

3. Crofthead Black Band lies below the last workable coal seams, is about eighteen inches thick. It is also found at Langside and Shotts.

4. Shotts ironstone. These overlie the Shotts Laigh coal, and consist of a thin band, with rich nodules containing bivalve shells.

The limestones associated with the upper field are seen at Levenseat, where there is an arenaceo-calcareous band of eight feet in thickness. At Gare there is a band three feet thick, with clay above and below; and at Millcroft, New Monkland, a bed five feet thick. The same limestone bands crop out in the vicinity of Glasgow, and at Oakbank, near Port-Dundas.

The lower basin consists of three beds of limestone, with marine fossils, the lowest bed being the best. It is wrought at Wilsontown, Carluke, Climpy, &c.

In this basin there are altogether fifteen beds of coal. The Main coal at Wilsontown, Carluke, and Climpy, lies from twenty-eight to thirty-two fathoms below the lowest of the upper limestones. It corresponds in position with that found at Netherwoodside and Temple, to the north-west of Glasgow, at Calderside, in the parish of Blantyre, and at Auchinheath on the Nethan. To the north of Glasgow this coal contains a few inches of cannel or gas coal. The great supply of gas coal in Glasgow, however, is from Auchinheath and Nethan-foot, where the seam averages twenty inches in thickness.

The shales of this lower basin contain numerous bands of clay-ironstone; some of them are four feet in thickness. The shale above the third limestone contains the greatest quantity of this mineral. The bands amount to fifteen. There is also a rich ferruginous deposit in connection with the cannel coal, consisting of several bands of ironstone. The nodules and bands above the main-post are also of very superior quality.

The whole coal basin is traversed by numerous faults and trap veins. Where these latter come in contact with the coal, it appears charred and altered. This is well seen at Airdrie Burn, and other places.

A range of trap rises to the surface on the north-east of the basin at Shotts, and on the south-west is a similar range of trap-hills in the parishes of Strathaven, Kilbride, and Carmunnock.

There are three trap dykes which traverse the district. The first is seen crossing the county between Snabe Limeworks and High Drumclog.

On the north of the county, two trap dykes, nearly parallel to each other, run from east to west. They vary in width from thirty to forty yards. They rarely run above the surface, except at Clayden and Cameron, where they rise into four ridges forty feet in height. Bedley tunnel intersects the south dyke, and it is there seen cutting through the blue limestone and the accompanying strata. The shale in contact with the trap is burned white, and the limestone is much indurated.

There remains to be noticed a bed of red sandstone superimposed upon the upper coal series, and which extends from Cadzow Castle, on the south, to the Calder Water, on the north. It consists of two or more beds of red and variegated sandstone, alternating with variegated shales and marls. These marls underlie a bed of red sandstone on the Avon, between Barncluith and Cadzow Castle, and they are superimposed upon two thin seams of coal, varying from one to one foot and a half thick. Immediately below these coals there lies a bed of reddish coloured rock, eighty to ninety feet thick, which is the lowest red coloured bed. In some places this bed passes into a white rock, and is frequently variegated with stripes, and spots of red and white. In the sandstone, masses of more indurated matter are met with, of concretionary origin.

On the whole, there are some grounds for supposing that this bed is not conformable to the coal-beds immediately below, although the same faults dislocate both strata. It may probably belong to the lower beds of the new red sandstone.

Renfrewshire.—From Port-Glasgow to Ardrossan, along the north side of the Clyde, the old red sandstone prevails, with a general dip to the north and north-east, and occasionally to south or south-east. Its highest elevation inland does not exceed 600 feet. This formation is interrupted by a mass of trap, which stretches along the whole northern part of the county, and extends southward into Ayrshire and Lanarkshire.

Along the southern side of this trap formation, the coal basin extends to the east in the valley of the Black Cart water, and to the west in that of the Garnock.

Coal is wrought at Quarrelton, Lochwinnoch, Lochhead, and Narvelston. At Hurlet, coal has been wrought for nearly 300 years. The bed is five feet three inches thick. It is highly probable that coal exists along this part of the county to Glasgow.

Coal is also found in the parishes of Stevenson, Kilwinning, Dalry, Kilbirnie, and Beith.

Limestone also abounds, and crops out at several places along the edge of the trap hills.

A fine-grained compact sandstone is also abundant in the coal measures.

The coal strata of the north of Ayr are found in the adjoining valley to the above, through which flows the streams Leveran on the east, and Lugton on the west.*

Accumulations of marine shells have been found in various localities in the valley of the Clyde lying above the common deluvium or *till* of the county, which would indicate a change of level or elevation of the land, at a period comparatively recent, and, at all events, subsequent to the deposition of the ancient deluvium. Twenty-five species of marine shells, differing from any known British species, were discovered at Dalmuir, in Dumbartonshire, by Mr T. Thomson. Mr Smith of Jordanhall, from the same locality, obtained about fifty species more, and this gentleman, prosecuting the inquiry still farther, has discovered marine shells in numerous localities, at considerable heights above the primal level of the Frith of Clyde. He says,* "When once I was furnished with a clue, I found them in places where their presence had never before been suspected, sometimes in great numbers, whilst at others the very same beds were altogether destitute of them. This is peculiarly remarkable in a finely laminated clay which I have traced to a great extent in the counties of Lanark, Renfrew, and Dumbarton. It is equivalent to the Carse clay of the Forth and Tay, and must have been deposited at the bottom of a tranquil sea, at such a depth as not to have been disturbed by the agitations of the surface. The shells and other marine remains with which it abounds are almost invariably found in the lower part of this bed, a circumstance which can only be accounted for by supposing a sudden depression which has converted a half-tide deposit into a deep sea one. The testacea have thus been entombed alive in the beds subsequently formed, and their remains are preserved with all the perfection of recent specimens. Associated with this clay are frequently found extensive beds of pure gravel and sand, also destitute of organic remains, although there can be no doubt of their marine origin."

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* Montgomery, Prize Essays, Highland Society, vol. vi.

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* Edinburgh Philosophical Journal, vol. xxv.

Sea shells have also been found by Mr John Craig of Airdrie, ten miles to the east of Glasgow, at a height of 350 feet. They were found between a mass of blue till and a bed of yellow stratified clay which rested upon it.

A proportion of the shells thus found, in various localities, are identical with species existing at present in the Frith of Clyde, while the remainder are of species now found in very different climates and localities.

Ayrshire.—The southern portion of this county, like that of Lanarkshire, rests on the greywacke and old red sandstone formations. To this succeeds the coal measures. Mr Menteith thus describes

The Basin of Sanquhar.—"The river Nith having worn itself a passage through the greywacke ridge, which divides the basin of New Cumnock from that of Sanquhar, enters that of the latter. In this ridge amygdaloid rock occurs. The hills encircling this basin are of greywacke rock. These hills are loftier, and of more pleasing form than those of New Cumnock.

" The coal formation occupies the central portions of this basin. The different beds of coal, accompanied with beds of sandstone, shales, and clays, seem to rest upon the greywacke rocks.—The coal stretches along both sides of the Nith for about six or seven miles, scarcely exceeding two miles and a half in width. Its position is very irregular. The strata are frequently broken, thrown down, and, as the collier expresses it, are full of troubles. These beds of coal are crossed by two veins or dykes of basalt, which, in their course, alter the position of the strata. Near to these dykes the coal is charred, and of inferior quality. The coal of this basin has a splintry character, and not unfrequently contains pyrites. Of the twelve beds, ascertained by borings in different parts of the basin, the thinnest is only a few inches, and the thickest does not exceed five feet. At the north-west corner of this basin a smithy coal, used by blacksmiths, of a good quality, is found.

" No limestone underlaying the coal of the Sanquhar basin has yet been discovered. The ochrey yellow sandstone, the usual attendant upon coal, occurs on both sides of the Nith. That found on the east side of the river is of a bad quality ; but that which is met with on the west, near the mouth of the

Youchan, of a yellow-whitish colour, is an excellent building material.

"Some traces of ironstone are observed near Crawick Bridge; and traces also at that place are observed of black lead.

"Lying to the eastward of the basin of Sanquhar, in the greywacke mountains, are the great lead mines of Wanlockhead and Leadhills. The principal ore at both places is *galena, a sulphuret of lead*, which is found in great quantities. From seven to nine ounces of silver can be extracted from the ton of lead.

"Gold is found by washing the sand of the streams in the vicinity of these mines.

"The rocks separating the basins of Sanquhar and Closeburn assume the appearance of *greywacke slate* more than any other part. The stratification is in many places nearly perpendicular, and runs from north-east to south-west. At Burnmouth, a place about the middle of this ridge, which divides the basin of Sanquhar from that of Thornhill, it forms an indifferent slate. At Arkland, in the parish of Tynron, slates for roofing have been raised. Thus, there seems a slaty structure to extend from Glenochar, a slate quarry in Crawfordmuir, Lanarkshire, across the whole of Dumfriesshire in this direction; and probably it may be traced through Galloway, and ultimately across the north of Ireland.

"*Basin of New Cumnock.*—It is bounded on the west, north, and east, by greywacke, forming hills of no considerable elevation, far from pleasing in their outline. It is separated from the basin of Sanquhar by a ridge of greywacke, nearly three miles broad, in which amygdaloid is found. Its length is about ten miles, and its breadth five miles. The coal formation fills all the central parts of the basin, and even spreads itself on the east over the sides of the greywacke hills. *Coal* is worked in several places. It occurs near the surface, in thick seams, from nine feet to twelve. The coal of the best quality is found at the great elevation of upwards of 1000 feet above the sea, at Mansfield, on the north side of Corsinscon Hill. The coal there is chiefly the cubical, and is raised in very large square blocks. At that elevated situation there are three principal beds, of nine, eleven, and twelve feet in thickness.

"Imbedded in the twelve feet seam of coal, we meet with one of cannel coal, sixteen inches thick; and lately another bed of the same coal, twenty-two inches thick, has been found in another place. Both these are free from sulphur. The gas at Dumfries is chiefly prepared from this cannel coal. But the common cubical coal, rich in bitumen, and being all devoid of sulphur, is often used at the same town for the preparation of gas.

"The coal is associated with slate clay, bituminous shale, and ochrey yellow sandstone, and ironstone in balls is also found in some quantity.

"The *carboniferous limestone*, which underlies the coal of the New Cumnock basin, is found in great quantities, and may be said to fringe the coal of this basin.

"On the banks of the Afton, a tributary of the Nith, *galena*, or *lead glance*, occurs in the greywacke rocks, but it is worked to no great extent; and *graphite*, or black lead, is found at Craigman."

The basin of the Ayr also contains several beds of workable coal wrought at Newton, St Quivox, &c. These beds are cut off to the north by a range of trap hills, which skirt the shores of the county, and extend along Renfrewshire and the western shores of the Frith of Clyde. A range of trap hills also intersect the centre of the county of Ayr, and thus interrupt the continuity of the coal seams.

In the bed of the water of Ayr an argillaceous stone is found, which is extensively used as hones.

AILSA.—This picturesque rock is situated in the Frith of Clyde, at nearly an equal distance from the shores of Ayr and Argyle, appearing like the summit of a vast mountain rising abruptly out of the deep. It forms an irregular cone 1100 feet in height. The base is about 3300 feet long, by 2200 in breadth.

It is surrounded by deep water, so free from rocks, that ships sail round it with safety. There is a convenient landing place on the east side, formed by a beach of rolled pebbles. On this side, too, is the only access to the summit, the other sides being almost perpendicular. On the east side, at about a fifth of the height, there is a sort of prolonged stair, or shoulder, on which are the remains of an ancient tower of strength. Two springs of water also issue from this acclivity, forming in their course a marshy plain. A few goats, and innumerable gannets, or Solan geese, are the chief inhabitants.

The rock consists of a basis of greyish compact felspar, having small grains of quartz interspersed. Along with this are also seen minute particles of hornblende collected in small groups, and condensed towards a common point. It assumes a columnar form, these columns attaining the magnificent height of 400 feet. In the north end is a cave of considerable dimensions. Numerous trap veins traverse the rock, generally in a vertical direction.

THE PRIMARY CENTRAL DISTRICT.

PERTHSHIRE.—This extensive county occupies a considerable part of the central primary range of Scotland, and here the primary rocks assume their grandest and most extensive features, while their junctions and alternations may be studied with much facility. The central and northern part of the county consists chiefly of granite and gneiss. It is exceedingly mountainous, and contains the great Grampian range, extending from Cruachan, on the west, to the mountains of the Dee in Aberdeenshire. The valleys are frequently occupied by lochs and mountain streams.

The southern part of the county is equally mountainous. It consists chiefly of quartz rock, primary marble, and mica, clay, and chlorite schists. The south-eastern part of the county descends into the sandstone valleys of the great old red formation. Granite, and the older porphyries, disappear about Comrie and Creiff, and are succeeded by the felspar rocks, and the greenstoné, and basalt of the newer trap formations. These form the Moncrieff and Kinnoul hills.

A glance at the accompanying map will at once shew the boundaries just pointed out, as also the general outlines of the prevailing formations in the several localities.

Glen Tilt.—This valley is no less celebrated for its mineralogical appearances, than as being the spot where the Huttonian theory received its most remarkable and conclusive illustrations. On this latter account it must be an interesting locality to every geologist. Through this valley flows the Tilt, the Tummel, and the Garry, and in the courses of these streams, the different strata may be traced for many miles. The prevailing rocks are quartz rock, mica, and hornblende schist, clay schist, and primary limestones, of various colours, from a dark blue to a grey, white, green, and variegated marble. At several places masses of granite are seen traversing these strata, sending innumerable ramifications of veins into the broken up and fractured schistose rocks. This is particularly well seen at Gow's Bridge, as well as in various other parts of the banks of the Tilt and Tummel.

A very extensive formation of limestone constitutes the whole of the left boundary of Glen Tilt. Its prevailing colour is dark blue, but it also assumes various other tints, and affords some of our most beautiful and ornamental marbles.

Beds of a nearly pure white marble are also found, but it is rendered almost unfit for the purposes of the statuary, in consequence of its containing a considerable quantity of mica disseminated through it.

It is of a larger grain, and a more compact texture than the Pentelican marble, of which the Elgin statues are formed, and which also contains mica, but when polished, the two can scarcely be distinguished from each other. Besides mica, *steatite* and *noble serpentine* are found mixed with the white marble of Glen Tilt. *Talc* is found in abundance, as also *tremolite*, and more rarely *asbestus.*

From Blair Athol to Castleton of Braemar, an uninterrupted range of quartz rock prevails.*

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* Macculloch, Geological Transactions, vol. iii.

Hill of Kinnoul.—This hill stands immediately to the east of Perth, on the banks of the Tay, above which it rises 600 feet. It is composed of an amygdaloidal greenstone, the base varying from a compact felspar to greenstone and basalt.

It is full of nodules, varying from the size of a filbert to that of a pear, or even a grain of mustard. They are composed of a green chloritic earthy substance, or of calcareous spar, quartz, or chalcedony. This last, streaked and variegated with many colours, forms the agates so much prized as ornaments.

Besides the nodules, veins of quartz and calcareous spar traverse the rock. Small portions of that rare mineral, heliotrope, have also been found. On the top of the hill a mass of trap tuff, or trap conglomerate, rests, and about the middle of the broken face of the side of the hill is observable an entangled mass of red sandstone. On the eastern base rests a stratum of greywacke slate, and to this succeeds the red sandstone conglomerate of the district.

ARGYLESHIRE.—This county extends from the Mull of Cantyre, on the south, to near Fort-William, on the north, and then embraces a considerable portion of the western shores and islands of Scotland.

The general surface of the county consists of the primary schists. The old red sandstone conglomerate fringes the west coast, and is seen in numerous localities in interrupted patches. The Mull of Cantyre consists of primary schists and primary limestone ; to this succeeds the old red sandstone, and from Campbelltown westward, the *oolitic* strata of the Western Islands prevail.

At Inverary a range of trap rock intersects the primary schists—these primary schists form the borders of Loch Awe, and then succeed a granite range of mountains, of which Cruachan is the chief.

The islands connected with this coast will be described in another section.

Bencruachan forms the highest and most conspicuous of a group of mountains, bounded on the south-east by Loch Awe, on the south-west by Mid-Lorn, on the north-west by Loch Elwin, and extending on the north-east in a continuous line to join the ridges of Schehallien and Ben Lawers. Here, amid the prevailing strata of primary schist, granite, porphyry, and trap are found, side by side, and assuming all variety of forms. Bencruachan forms a base of wide circumference, and raises its huge bulky top to the height of 2459 feet. Its sides are composed of a compact mica slate, mingled with a clay slate, varying from dark lead grey to greyish green. Beside the high bridge over the river Awe is a patch of sandstone, consisting of a lower red bed surmounted by a white calcareous grit, corresponding to similar patches of the old red sandstone found in various other localities of the primary range. On the shores beyond Bunawe, the junction of the granite with the schistose rocks is very distinctly exhibited. Large veins may be seen proceeding from the mass of the mountain, and ramifying into innumerable small veins in the slate. Two distinct granites appear in this place, one consisting of reddish felspar, quartz, and mica, the other a syenitic compound of white felspar, mica, and hornblende. These two appear to have been co-existent, and pass into each other.

The great central mass of the mountain is of granite, of that kind formed of an equal mixture of reddish felspar and white quartz, with a small proportion of mica, a similar granite, in every respect, to that of the Cairngorm mountains. Veins of porphyry traverse this granite in all directions, both at the base and summit of the mountain. The veins are of different sizes, as well as aspects, varying from the breadth of three or four feet to that of fifty or more; they, in a general view, appear perpendicular.* They traverse both the schist and the granite, but keep separate, and intermix with neither, nor apparently do they produce any disturbance in the course or direction of these rocks. Two veins, of totally different colour, may be seen running parallel to each other, but never communicating. The principal kinds are, a brick red porphyry, a reddish grey, a dark grey, with crystals of white felspar, a purple, a brown, and a dark green uniform mixture of hornblende and felspar. Together with these veins of porphyry, various parts of the mountain are intersected by veins of a greyish trap rock and a black basalt.

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* Macculloch, Geological Transactions, vol. iv.

The same kind of granite as that of Bencruachan is again seen forming the extensive elevated level, called the Moor of Rannoch. At Glencoe, again, porphyritic rocks prevail, while a mass of trap extends from Cruachan to the shores of Oban.

The granite of Ballahulish is of a light grey colour, and different from that of Bencruachan, just described.

Along the shores from Oban to Ballahulish, huge masses of the sandstone conglomerate are visible, on one of which masses the ancient vitrified fort of Beregonium is situated. This fort has evidently, like others in Scotland, been constructed of dry stones, and afterwards vitrified by the application of intense fire. On some of the masses of half vitrified gneiss we discovered evident impressions of the ligneous fibre remaining, as also indications of marine fuci having been employed in the process. Primary limestone is met with on the northern side of Loch Etive.

At Ballahulish is an extensive slate quarry. Here, and at the island of Eisdale and Luss, in Dumbartonshire, is the chief supply of roofing-slates obtained. At Ballahulish 200 workmen quarry out and prepare three millions of slates annually.

Strontian.—Between Ballahulish and Strontian, which lies on the west side of Loch Linne, the succession of the primary schists, resting on granite, is visible for several miles. At Strontian, near the junction of the granite and gneiss, is a vein of lead ore associated with iron pyrites, *calcareous spar, foliated zeolite, heavy spar, and strontia.* Of this vein different branches have been wrought. On the opposite side of Loch Sunart indications of copper are also visible.

Ben Nevis.—This huge and rather unshapely mountain rises almost from the neighbouring shores of the sea, without any previous elevation of the county forming its base, to the height of 4370 feet. Viewed from the west, it appears to consist of two distinct parts, the smaller, or round backed summit, seeming to be piled upon the lower mass. It is, in fact, composed of two distinct formations. Its sides are almost perpendicular, which renders the ascent difficult. At an elevation of about 1800 feet there is an irregular platform, with rising ground on each side. This plain inclines upwards to the right, and where the steepest part of the top of the mountain commences, there is a hollow containing a small lake. Beyond this the rocks are bare, rugged, and destitute of vegetation. The part of the ascent, or face of Ben Nevis, to which this description applies, is from two to three miles from the summit, and the whole distance from the lowest to the highest point may somewhat exceed five miles. On the northern side, or back of the mountain, it is encircled by a high ridge, which, after sweeping round the intermediate hollow, joins Ben Nevis on the south, at the height of nearly 1000 feet below the summit. The circumference of the base may be about twenty-five miles. Towards the north the mountain slopes gradually till it terminates in the valley of Loch Lochy. Numerous streams flow down the sides, and thus expose the rocks in natural sections.

The precipitous sides at the north-east afford the best view of the rocks composing the mountain, which are as follow:

The base consists of gneiss, mica slate, and clay slate, seen resting on the central rock on each side. This rock, a little above the base, consists of a greyish granite, or syenite, being composed of felspar, hornblende, and mica. Higher up this changes to a beautiful reddish rock of a porphyritic character, where the felspar assumes a regular crystalline form. In the Claggan Burn, a vein may be traced ascending upwards, composed chiefly of felspar, with a slight intermixture of hornblende, mica, and quartz.

After passing the small lake, and at about two-thirds of the ascent, the rock again changes to a greyish-black, or deep green, with a uniform texture approaching to that of basalt. It rests upon the red porphyry below, with a well-defined line at the point of junction. In ascending, the rock gradually assumes a porphyritic appearance, large crystals of reddish felspar being embedded in the dark green base. On the summit these crystals nearly disappear, and the rock again assumes its uniform basaltic character.

The precipitous side of Ben Nevis, and the junction of the black and red rocks, will be best seen by following the course upwards of the Mill Burn and Stone Burn. Here the majestic mass of rocks, of different dates and formations, may be viewed to the utmost advantage. "Its magnificence and wildness, indeed, baffle description, and cannot be conceived without being seen. From the west, Ben Nevis appears only an object of immense magnitude, without elegance of outline or picturesque beauty; but on this side language fails in attempting to paint its awful grandeur and terrific sublimity."*

In Glen Nevis, a beautiful red granitic compound of pinkish felspar and quartz is abundant. Trap veins are also found traversing the strata similar to the rock forming the summit of Ben Cruachan. On the west side of the mountain, a vein of lead ore was found many years ago. Gold is also said to have been found to the south-east.

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* Dr Macknight, Wernerian Transactions, vol. i.

In Glen Nevis, M. Agassiz has pointed out accumulations of boulder stones illustrative, as he supposes, of the operations of ancient glaciers, and ana logous to similar translations of boulders in the valleys of the Alps, which are in operation in the present day.

Parallel Roads of Glen Roy.—These celebrated indented lines, which have attracted the attention of all travellers and geologists, are situated in Glen Roy, a lateral branch of the larger Glen Spean, about ten miles to the north of Fort-William. Glen Roy is about four miles in length, and one mile in breadth, with pretty steep sides. The stream Spean falls into the river Lochy, near Loch Lochy, and the Roy falls into the Spean five miles eastward. On both sides of Glen Roy there are three narrow terraces, or *roads*, formed of gravel and clay, called the "Parallel Roads." They project several feet from the sloping side of the mountain, forming three slightly marked lines along the valley, from end to end, and exactly parallel to each other. At some parts they are not to be seen, such as where they cross the bare hard rock, where loose soil or gravel would not rest, and where the surface of the hill is gently inclined, because this slope then coincides with that of the alluvial cover. Very often the appearance is so faint that a spectator may find himself standing in one without being aware of its existence; but, at other parts, they swell out into pretty broad terraces, and what seemed obscure to a spectator, in juxtaposition with it, becomes more distinct when seen from the opposite side of the valley, where the eye takes in the line for a length of some miles. Each of these terraces, by the test of the level, has been found not only horizontal in its individual bearing longitudinally, but also horizontal as regards the corresponding terraces on the opposite side. The first, or lowest terrace, is 972 feet above the level of the sea; the second is 1184 feet; while the third is 1266 feet. The base of the terraces has an inclination towards the centre of the valley. In the valley of Glen Gloy, in the vicinity, which is separated by a ridge of high ground of about half a mile thick, there is a terrace twelve feet higher than the highest in the former, or 1278 above the sea level, but none lower. There is a remnant of a similar terrace at Kilfinnan, four miles northward, which is forty feet higher than the highest in Glen Roy, or 1306 feet above the surface of the sea. The three terraces of Glen Roy follow the line of the valley down to its junction with Glen Spean, passing into all its sinuosities and recesses. Here two of them disappear, but the lowest continues its course up to the head of Glen Spean, and down nearly to its mouth, over a space of twenty miles, always preserving the same level. Portions of terraces have also been traced on the sides of the valley of the Spey, many miles eastward of those just described, and at a height of about 800 feet. Sir T. Dick Lauder and Dr Maculloch, who both, about the same time, described these roads, account for their formation thus:[*] In lochs which have steep banks covered with somewhat loose materials, rains and storms hurry down earth and stones, which have their motion checked when they reach the water, and thus form a projecting ledge or shelf, which is nearly on a level with its littoral surface, and slopes gradually inwards below its water, so that if the loch were partially drained, a circular terrace would thus be left at its former margin. If a second and third drainage took place at certain intervals, other terraces would thus be formed, till the whole waters were evacuated.

It has been supposed, then, that Glen Roy, Glen Gloy, and Glen Spean, originally formed distinct lochs, each closed in by a barrier at its end;—that the barrier at Glen Roy gave way partially, so that the waters of the loch rushed out to a certain extent, and left the highest terrace; succeeding evacuations formed the second and third terraces, in a similar manner, till, at last, the loch was completely emptied. At the period of the formation of the lowest terrace, it is supposed Glens Roy and Spean formed one continuous line of water, because the same terrace extends along the side of Glen Spean for twenty miles, while no trace of the higher terraces are found in the latter. Glen Gloy is supposed to have formed a distinct loch with the water elevated twelve feet above the others, when its barrier giving way, it was at once emptied without the formation of any more terraces. It must be admitted, however, that no vestiges of terraces, or indications in the strata that such existed, are now to be found. Mr Darwin has lately proposed another theory—that the terraces are sea beaches formed at the period when the how elevated land constituted a low and level bay of the ocean, and that the periodical elevation of this land gave time for the formation of two or three littoral indentations. Mr Darwin illustrates his theory by analogous phenomena in Peru.*

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[*] Transactions of Royal Society of Edinburgh, vol. ix.—Transactions of Geological Society of London, vol. iv., first series.

The country around Fort-Augustus, and about Loch Oich, and the head of Loch Ness, is mountainous and irregular. Gneiss and mica slate rest on granite, and this formation continues till it is met by the old red sandstone.

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* Edinburgh Philosophical Journal, vol. xxvii.

THE OLD RED SANDSTONE DISTRICTS.

FORFARSHIRE.—This county, in its northern division, embraces part of the great primary range of the Grampians. The granite of these mountains bounds the northern extreme edge of the county, and to this succeed gneiss, mica schist, clay slate, and greywacke, each of these formations in succession, occupying a tract of considerable extent, and each observing a north-east and south-west direction.* Immediately on the clay slate rests a series of strata, consisting of red and green shale, of grey micaceous and slightly calcareous sandstone, and of red schistose sandstone.

This inferior series appears to be analogous, both in position and character, to the tilestone, cornstone, and marl of the English counties of Hereford, Gloucester, and Monmouth. One of the most remarkable fossils is the *cephalaspis Lyellii.* The Arbroath slates belong also to this deposit.

This inferior bed dips beneath the old red sandstone conglomerate, which flanks the Grampians, and emerges again on the south side of the valley of Strathmore, constituting the Seidlaw chain of hills. The strata in that chain are disposed saddle-wise, and along the axis, or anticlinal line of the saddle which runs north-east and south-west, the oldest members of the inferior sandstone series are displayed lying almost horizontally. The newer members of the same series dip away from the axis on either side, with an inclination constantly increasing as they recede from it. The strata dip with great regularity to the south-east along the coast from Dundee to the Red Head; but to the westward the inclination is to the north-east; this change takes place suddenly to the west of Dundee.

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* Lyell, Geological Transactions, vol. iii.

The eastern part of the great valley of Strathmore is composed entirely of old red sandstone. The strata are disposed in a trough, those on the northern side of the anticlinal line dipping rapidly to the south, and occupying consequently a narrower space than the corresponding strata on the southern side, which dip more gradually in an opposite direction. The lowest stratum of the sandstone is a conglomerate, the outcrop of which forms a range of low hills on either side of Strathmore, one range, to which the Alyth hills belong, flanking the Grampians, the other, which comprehends the hills of Finhaven, flanking the Seidlaws. Above the conglomerate is a series of red sandstone strata, which yield an excellent freestone, and above these are some very argillaceous beds of a deep ferruginous red colour, provincially termed calm.*

In these beds are found scales of *holoptychus*, as at Clashbinny, Perthshire; and in the lower beds remains of other fishes, as dipterus, osteolepis, &c.

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* Lyell.

A deluvial gravel and clay of great depth, in some places, covers the sandstone formation, and on this rests a considerable depth of rich alluvial soil.

We shall now point out the localities of these beds along the estuary of the Tay:—

Grey sandstone first makes its appearance at the eastern edge of the basin at Invergowrie quarry, about three miles west of Dundee. It is here in thick beds and close-grained, of a pale grey colour, slightly tinged with red, and containing occasional small scales of mica. It dips at an angle of about fifteen degrees towards the north-east. The upper strata of this stone are very compact and hard, and rise to the tool of the quarryman in blocks of enormous size and solidity. It is well defined in its mineralogical characters. It never contains marine remains, and rarely those of land animals. In most cases it is marked with black carbonaceous impressions already described. The limits of this rock are pretty well defined by the frequency with which it appears near the surface at places where other formations, of a different sort, are visible at no great distance. These indications point out to us somewhat definitely the bounds of the basin of included red sandstone, characterized by the brightness of its colour and the spherical grey spots with which it is marked, but more particularly by the abundance of marine remains, especially of fishes, by which it is distinguished. The grey sandstone, possessing in most cases the whole of the characteristics alluded to above, and in all the greater part of them, is found at the following places: On the east we find it at Invergowrie, with trap a little way to the eastward of it; from this it stretches northward, and is worked on a large scale at Lochee. Tending northwards, it fills up the valley of Strathdighty, and covers the Auchterhouse division of the Seidlaws. Proceeding from Lochee westward, we find it quarried close by the church of Liff. It again appears in the channel of the Burn of Fowlis, and at the top of Balruddery Den, greatly disturbed at the latter place by the proximity of trap-dykes. Here have lately been found, besides the vegetable organisms already mentioned, the remains of fishes and of a gigantic lobster. To the north of Balruddery, it dips at an angle of fifteen degrees west-south-west. It is visible near the farm of Dron, and has been worked to a considerable extent to the north of Rossie Priory, near the Littletown. It fills up the valley of the Lochtown, in the bosom of the Seidlaw hills, and is seen reposing on the grey slate pavement beds. Passing from Rossie westward, we have it quarried at Ballendean, interstratified with rock, marl, and coarse limestone. It again appears at Kinnaird Castle, after which we lose sight of it for several miles till we have got to Aberdalgie, some way in Strathearn. It may, however, be supposed to hold its way to the south of Glendoick and Glencarse, crossing the Tay to the westward of Pitfour, and skirting the trap of Moncrieff Hill to the north of the quarry of the Hilltown. Over this track so thick a mass of diluvial matter prevails, that the surface of the rock has nowhere been disclosed. It is not unlikely that the edge of the grey sandstone here presented may be a narrow one, or that it may be altogether overlaid by the marine red sandstone, or an efflux of the trap. At Aberdalgie it appears in abundance, and is quarried to a considerable extent a little way north of the church. It is here devoid of organisms, but is very distinctly marked. It is of a pale grey colour, fine-grained, and contains a considerable quantity of rock marl, and earthy limestone in rounded nodules. It is again seen at the bridge of Forteviot, and, two miles further across the valley, is extensively worked at the village of Dunning. In both these cases it is quite full of organic impressions, of a magnitude and distinctness which has sometimes made it to be mistaken for the carboniferous sandstone of the coal formation. Though rarely visible, it is probable that here it occupies a large space on both sides of Dunning. It constitutes the greater part of the high grounds about Gask, and stretches north in the direction of Huntingtower. The southern boundary of this basin, from Dunning to Newburgh, can only be conjectured, as sandstone is only in few cases apparent. At Parkhill, to the east of Newburgh, a thin bed of it is found dipping under the trap. This bed again manifests itself at Birkhill and at Balmerino, in similar positions, and abundantly marked with vegetable remains. It is not visible on the north coast of Fife farther east than Balmerino. Crossing the Tay to Invergowrie Bay, we find it quarried to a great extent at Kingoodie. Two miles north-east of this is Invergowrie quarry, the point from which we started.

The red sandstone is, if possible, better marked than even that which has just been described. It is for the most part stained of a bright red colour by the oxide of iron. In some places, as at Inchture, bright grey spots of a circular form are thickly sprinkled on this ferruginous ground. In the centre of these, fish scales have occasionally been found. Entire specimens of fish have not unfrequently been discovered in this bed, and fragments of the bones, and more especially of fish scales, characterize the whole formation. Its beds are generally pretty nearly horizontal. The enormous mass of clay accumulated on its surface causes it to be but rarely wrought. It is quarried to the north of Castle Huntly, at Inchture, at Clashbinny, and to the east of Pitfour. In the eastern part of Strathearn, the red sandstone quarry of Hilltown, not far from Aberdalgie, seems to be analogous to that of the Carse of Gowrie. Clashbinny is celebrated for its fossils. A mass of red sandstone is seen dipping under the trap at the mouth of Glenfarg, south of Aberargie, and not far from Abernethy. This seems to belong to the Clashbinny rocks, a small outlayer of which most probably stretches through the opening at Denmiln, as the relics by which they are characterized have been found to the westward of Collessie, as well as in thin beds of rock to the eastward of Lindores.*

Bakie Loch, in the parish of Airly, nine miles west of the town of Forfar, at one time extended over 200 acres of land. It was partially drained about ninety years ago, and the now dry margin exhibits strata of peat and marl, the latter, in some places, ten feet deep, and containing large horns and bones of stags and bulls, tusks of the wild boar, innumerable shells of fresh-water testacea, and vegetable remains, especially the seed-vessels of the chara.

There is another similar deposit of marl at Kinnordy, six miles south-west of Bakie Loch, containing a marl formed of the minute young shells of the fresh-water testacea, among which are also found the seeds of the *chara hispida.* There are two kinds of marl, an upper and a lower, with a layer of clay intermediate, and peat-moss above all. In the upper marl the skeleton and horns of a stag, of very large dimensions, were found; and in the peat above a very ancient canoe, hollowed out of oak, fifteen feet long, without any marks of row-locks for oars, thus affording grounds for believing that it was a paddle canoe of the primitive inhabitants of the soil.

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* Buist.

The northern portion of Forfarshire is elevated, and has all the ungeniality of a soil and climate of a primary range of strata. The lower and middle divisions of the county are extremely fertile. This is especially the case along the banks of the Tay. This river, at a remote period, must have occupied a considerably broader space than at present. Indeed, the quantity of silt which is continually carried down by the tides and currents has a constant tendency to fill up and narrow its channel. This reclaiming process goes on naturally, but it is also aided by art to a considerable extent between Perth and Errol.

The alluvial contents of the valley of the Tay consist chiefly of three distinct varieties of clay: till-end clay, and Carse clay, as they are called in the locality, together with black loam, gravel, sand, and peat-moss. Immediately on the surface of the red sandstone throughout the Carse of Gowrie, lying conformable with it, and covering it to a depth of from one to six feet, is an undulating stratum of red clay or till, full of rounded pieces of stone, and abounding more immediately on the surface of the rock, with large angular fragments of the rocky material on which it rests. This forms a cold retentive subsoil, and when brought into cultivation, a wet and unproductive soil. Over certain parts of the Carse, what is called end-clay prevails, and is sometimes found to the depth of thirty feet. It is of a yellowish-white colour, frequently stained with the hydrate of iron. The peculiarity of this structure, from whence it receives its name, consists in its utter want of stratification. It has a semi-crystalline appearance, like imperfectly dried wheaten starch. It is exceedingly unproductive to the farmer, being not only destitute of the nutritive stimulants of plants, but in moist weather it becomes so wet and soft that it is impossible to work it. When crops have taken root in it, it will not always retain them. It rises and swells in March with the frost, and when it subsides again, leaves the plant thrown out behind it; while any excess of drought causes it to assume the cracked and crystallised aspect to which we have alluded. It has been observed, that oak trees, when planted in it, having in vain sought nutriment by pushing their roots in all directions horizontally, thrust them downward in long perpendicular fibres, till they fairly get through the end-clay, whatever be its depth. Some of these have been measured twenty feet in length, and almost destitute of lateral off-shoots. End-clay is almost always found in beds of considerable thickness, and generally reposes on the till. It is chiefly to be observed from the river, on the bright coloured precipitous bank extending all the way from Port Allen west to the boundaries of Pitfour. The most important of all the alluvial matters, for the purposes of agriculture, is the Carse clay. This is a rich aqueous deposit, consisting of finely comminuted particles of silicious and argillaceous matter, the latter greatly predominating, commingled with rich putrescent vegetable remains. It is probable, that in all parts of the Carse this has been deposited in a manner somewhat similar to that which is presently going on at Pitfour, Errol, and Seaside. Carse clay of all kinds is generally interstratified with very thin beds of sand. In many parts, abundance of sea shells are to be found in it, though generally in a state of considerable disintegration. This is especially the case along the shores of Seaside where they prevail, chiefly about three feet above the present level of the tide, nearly ten feet under the surface of the ground. Around Errol, the immediate subsoil is a sharp ferruginous gravel, with a soil resting on it of fine friable fertile black land. The sloping grounds from the southern acclivity of the Seidlaw hills are covered with a reddish-brown soil, very suitable for the purposes of green crop, forming what are called the braes of the Carse. Two or three strata of peat, mingled with the leaves, branches, and trunks of trees, and with hazel nuts, and the more indestructible seeds, pervade several parts of the Carse. One of these is generally found about three feet under the present level of the river, at the mouth of the Earn. This rests immediately on a bed of about eight inches thick, of beautiful silvery-looking blue clay, resembling extremely comminuted mica. This reposes, again, upon till, and just over the peat is a thick bed of silt.

ABERDEENSHIRE AND BANFFSHIRE.—At Stonehaven, the primary strata of the great central range commences.

There is immediately below the old red sandstone conglomerate a band of clay slate, which can be traced in an almost uninterrupted line from this point to the western shores of the island.

To this succeed mica schist, quartz rock, and gneiss, the whole reposing on the granitic masses which form the range of the Grampians. Along the course of the Dee, upwards to its source, the county is elevated and mountainous in the extreme; the highest point of land in Scotland, the summit of Ben Macdhui, being situated in this direction. As the mountains approach the eastern shores, however, they gradually slope away to near the sea-level, and the district between Stonehaven and Aberdeen accordingly presents nearly a dead level, and extremely bleak slope, where there is a scanty moist soil, covered with stunted heath, and thickly strewed with boulders of various sizes, and fragments chiefly from the mountains to the westward. Between the rivers Dee and Ythan, granite is seen abundantly coming to the surface, forming rather large swelling undulations, instead of rising into hills of any great magnitude.

At Rubislaw and Grandholm quarries, in the vicinity of Aberdeen, granite is extensively procured, both for home use and exportation. A great proportion of the streets of London, as well as some of the bridges and public buildings, are built of this excellent and durable stone. At Grandholm, a vein of manganese exists in the mica slate, and has been lately wrought there.

The same primary range extends beyond the Ythan to the sea, at Peterhead and Fraserburgh, syenite being substituted for granite. A line, extending from a point about midway between these two towns, southwards to Kildrummie, marks out the commencement of the clay slate strata, which extend along the whole valley of the Deveron, westwards to Banff. At Gamrie, on the coast, and at Kildrummie, patches of the lowest beds of the old red sandstone conglomerate make their appearance, lying unconformably upon the clay slate. This conglomerate at Gamrie contains nodules of fishes, the *osteolepis, dipterus,* &c.* Boulders and detached fragments of lias and oolitic strata are also here found, and in the vicinity of Banff, unequivocal traces of the chalk formation have been discovered.* A greenstone dyke is also found intruding into the strata at Gamrie. At Portsoy is the well-known vein of beautiful green serpentine, of a soft alumnious structure, easily susceptible of a smooth polish. Clay slate is also abundantly developed in the Foudlin hills between Pitmauchie and Huntly, where extensive quarries of this substance for roofing-slates are wrought. About Old Meldrum, and extending westward, syenitic and hornblende rocks are also to be seen *in situ.*

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* Prestwich, Geological Transactions.

The country from Cullen, southwards, to the base of the Cairngorm mountains, forms the greater part of Banffshire. Mica schist, talcose schist, and quartz rock prevail, with few interruptions. Primary limestone is also partially found in this district, and in some situations it is quarried and made into lime. The Cairngorm mountains have long been celebrated for their topaz crystals. They are not, however, found in such abundance as formerly. Crystals of fluor spar have been procured in the limestone strata to the eastward of these hills, and in Strathdon a vein of lead ore exists in such quantity as to have attracted the attention of the proprietor, who, it is said, proposes working it. At Boharm, in a vein of talcose slate traversing quartz, Dr Maculloch discovered the mineral *sappare.* A few miles eastward of Speymouth the old red sandstone, chiefly its middle and upper beds, is met with, and this formation continues to skirt the whole coast district onwards to Inverness and Beauly.

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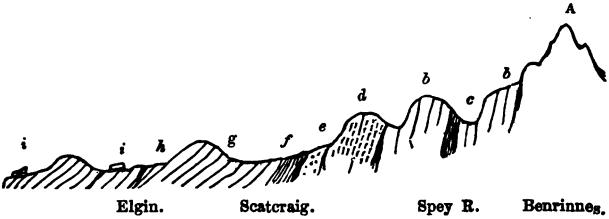
* Christie, Edinburgh Philosophical Journal.

ELGINSHIRE.—This county slopes in a succession of parallel mountain ridges, with intervening valleys from the elevated range of the Cairngorm mountains on the south, to the shores of the Moray Firth on the north, and this slope exhibits a succession of strata indicated in the accompanying section:



A Benrinnes, formed of a reddish granite; *b* gneiss and mica schist; *c* talcose schist at Craigellachie, on the river Spey; *d* gneiss and quartz rock; *e* coarse sandstone conglomerate; *f* red sandstone and fish beds at Scatcraig; *g* yellow sandstone, with one or more bands of unfossiliferous limestone, as at *h*; *i i* Linksfield fresh-water beds, and oolitic strata at Lhanbryde, Inverugie, &c.

The country consists of three great valleys extending in a direction from west to east;—the valley of the Spey, the valley of the Lossie, and the coast valley, terminated by the Firth. The first is an alpine region, bounded on the west and south by the Cairngorm range of granite mountains, commencing at Granton, and terminating with the northern limb of this range, Benrinnes. Here granite, gneiss, mica slate, and quartz rock, follow each other in succession. Between Cairngorm and Benrinnes, a quartzose rock is very prevalent, at Craigellachie a talcose schist rock is visible; this is succeeded by a quartzose conglomerate; and at Dallas, on the banks of the Lossie, quartz rock and mica schist are again visible.

The middle valley is bounded by the Dallas hills on the south, and the Quarrywood hills on the north. Here the old red sandstone conglomerate commences, with its characteristic ichthyolites, and these beds are succeeded by a yellow quartzose sandstone, with one or more bands of limestone, constituting the upper portions of the old red formation. The coast valley consists fundamentally of the yellow sandstone, with superimposed patches of lias and oolitic strata, and is also covered with a rich deluvial clay and loam, constituting the most fertile part of the county.

At Scatcraig, about five miles south of Elgin, the middle red conglomerate *b* of the old red sandstone crops out, and has been found to be rich in the scales, bones, and teeth of the *holoptychus nobilissimus*.* This formation is also found at Tynet Burn, to the east of Fochabers, at Dipple, on the banks of the Spey, and also on the banks of the Findhorn; and at Lethan, besides the *holoptychus* and other fishes, the *pterichthys* and *coccosteus* have also been found in these latter localities. This bed corresponds, both in its mineralogical characters, and in its organic remains, to the corresponding bed in Forfarshire and Fifeshire, as well as to those at Cromarty and in Caithness shires. The next strata above this conglomerate is the yellow silicious sandstone, which exists in this county in great thickness, and to a considerable extent, forming the hills of Pluscarden, Quarrywood, and Covesea. One or more bands of an impure concretionary limestone (cornstone) are also found either above or below, or perhaps it may be alternating with this sandstone. These have been quarried and burnt into limestone, at Sheriffmill, Linksfield, and Inverugie. On the shore of Stotfield this limestone band is seen lying above the yellow sandstone. The yellow sandstone is homogeneous, close-grained, hard, and durable, and forms a beautiful and useful building material. It, in general, contains few traces of organic remains in this county, although lately scales of the holoptychus have been found in it. It seems to be identical with the yellow sandstone of Dura Den, in Fifeshire. In the accompanying limestone no organisms have yet been discovered. It is marked occasionally by dendridic crystallizations of iron.

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* Mr P. Duff.

It has more the appearance of a drifted sandstone, accumulated suddenly by currents, than the inferior beds, which seem to owe their existence to a gradual tranquil deposition. In the yellow sandstone the traces of stratification are often not very distinct, nor are there those regular bands of shale which characterise the regularly deposited sedimentary beds of other localities. Perhaps this drifting process, too, may account for the paucity of organic remains. A little to the north of the village of Lhanbryde, a small patch of strata exists, containing fossils and vegetable impressions of *equisetaceæ* of the lower oolite and lias formations. Shells of the lower oolite are also found in detached patches of rocks near Inverugie.

At Linksfield quarry, about a mile north of Elgin, lying above a band of limestone, is found a fresh-water formation corresponding, in some respects, with the Wealden beds of England. It consists, 1st, Of a blue clay, with thin beds of compact shelly limestone; 2d, Bands of limestone and clay; 3d, Dark-coloured clay; 4th, Compact grey limestone with shells; 5th, Greenish earth or clay; 6th, Red sandy marl inclosing rolled pebbles of granite, gneiss, and fragments of red sandstone.

These beds contain the dorsal spines of a species of shark, and vertebræ of Saurian reptiles; the teeth and scales of ganoid fishes, similar to some of those found in the Burdiehouse limestone; a *modiola*, *cy-*

clas, and *cypris*, with oval compressed bodies resembling seeds of some vegetable.

The bed of the river Lossie, between Birnie and Dollas, exhibits traces of the existence of a former lake, the margin of which can be very distinctly traced in the remaining headlands elevated a considerable number of feet above the present course of the stream, and exhibiting a level line of shore for a considerable distance.

The lower, or coast valley of the district, seems also, at no very remote period, to have been elevated a considerable height above its former level. Thus, at Pitgaveny, now three miles distant from the sea, there are found deposits of clay containing shells of the oyster and *turbo littoralis*, at an elevation of ten to twelve feet above the present highest tide-mark. There are historical records to show also that the estuary of the Lossie extended much farther southwards than it does at present, and that the low lands from Kinnedar to Burghead, taking a semicircular sweep to the south-west, were at one period under water.

Along the sea-shore from Lossiemouth to Hopeman, a series of raised beaches are distinctly visible, with an almost continuous line of fissure of the sandstone, which appears to have been effected long after its consolidation. Marine shells of species existing on the shores at the present day are found at an elevation of from twelve to 200 feet above the present sea-level. Caves also, which appear to have been formed in the sandstone rock by the long action of the waters of the ocean, now lie considerably elevated above the highest tide-mark. One of those caves was lately discovered at Hopeman, about twenty feet above the sea-level, and 200 yards landward, and which contained marine shells of the existing species, together with the bones of several species of existing aquatic birds, and part of the jaw-bone and scull of a beaver; another proof joined to that of the existence of the skeleton of the beaver, in the alluvial deposits of Forfarshire, that this animal inhabited Scotland at a remote period.

A little south of the village of Lossiemouth are also visible a series of raised beaches, consisting of accumulations of water-worn pebbles, chiefly of the primary rocks, which appear to have been thrown up by the action of the tide. They extend longitudinally from south-west to north-east, and are now entirely removed from the action of the sea.

Sands of Culbin.—These sands extend from the western edge of the mouth of the Findhorn several miles along the margin of the Firth, and are remarkable as the locality of a large extent of fertile land, which, about a century and a half ago, was completely covered over with sand. The estate of Culbin, one of the most valuable in Moray, belonged to an ancient family of the name of Kinnaird. Between the years 1670 and 1695, in consequence of the drift of loose sand from the westward, the lands were overwhelmed to the depth of several feet, and the estate so much destroyed, that the proprietor in 1695 petitioned parliament to be exempted from paying the public dues, the greater part of the lands, and the mansion-house, farm-steadings, and orchards, being all ruined. The estate still remains completely covered over to this day, the only traces of its former existence being the occasional appearance of the ruins of houses, and portions of soil still retaining seeds having the power of vegetating, which are occasionally dug up. No satisfactory account of the manner in which this singular drifting took place, at that particular time, has been recorded. We know not whether it was a gradual or sudden process, or whether any remarkable state of the winds prevailed, or any change occurred in the ground in the vicinity, by which such an extensive disturbance and change in the surrounding sand was brought about.

It is said that the sand was borne from the westward and south-west, by the winds which prevail from that quarter, and the removal of it was accelerated by the country people pulling up the bent (*arundo arenaria*) from the ground to the westward. It is also difficult to account for the previous accumulation of sea-sand so far inland. Was it thrown up by the sea-waves, aided by easterly winds, or brought down by the detrital action of the rivers

Ness and Beauly? Or were the shores of the Firth raised above the sea-level by subterranean causes? The marks of comparatively recent elevations along the shores of the Firth, extending also to the beach in the vicinity of Culbin, would rather favour this latter supposition. During the eleventh century, Bœthius and Fordun make mention of an extraordinary commotion and inundation of the sea on the coasts of Moray. "In the year 1097," says Bœthius, "King Malcolm died, and in the same year Albion was terrified, by many most alarming prodigies, many villages, castles, towns, and extensive woods, both in England and Scotland, were overwhelmed in an exundation of the German Ocean, by the weight of which tempest the lands of Godowine, (Goodwin,) near the mouth of the Thames, were overwhelmed by sand, and likewise the land of Moray in Scotland was at that time desolated by the sea, castles subverted from the foundation, some towns destroyed, and the labours of men laid waste, *by the discharge of sand from the sea*, monstrous thunder also roaring horrible and vast." At later periods similar changes may have taken place on this coast, the effects probably of much more distant and extensive commotions in other regions of the globe, and these may have been so gradual, and even imperceptible in their immediate effects, as to have passed without much exciting the curiosity of the inhabitants. The line of fracture of the consolidated sandstone of the coast, already alluded to, as well as a remarkable appearance in a sandstone quarry, a little to the east of the Knock of Alves, where the strata have evidently been, at a comparatively recent period, broken up and fractured into large irregular masses, by a disturbing cause from below, would indicate that some upheaving power had been at work in the district. If we suppose, then, that the shores of the Moray Firth have been considerably raised above their former level, we have thus a large tract of arenaceous accumulation raised up out of the ocean, and exposed in such a way as to be easily drifted by the prevailing winds of the district. After this accumulation had been thus dispersed and levelled, the drifting process would again nearly cease, and we are not aware that at present any great movement is taking place in that locality.*

In the bay between Burghead and Findhorn there are traces in the sandstone of a submerged forest. Fragments of trees of considerable size, consisting of oak, pine, and birch, imbedded in peat moss, are occasionally cast up, and thrown ashore by the action of the waves.

The section of strata intersected by the river Findhorn exhibits the same succession as that indicated by the wood-cut in page 100. We have to the south the granite, with its accompanying primary rocks, and the old red sandstone, with beds of unfossiliferous limestone succeeding. The same formation extends around and through Nairnshire onward to Inverness.

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* See "Sketches of the Past and Present State of Moray." Edinburgh, 1839.

Section of cornstone bed at Cothall, on the right bank of the Findhorn, in descending order:

1. Green and purple coloured beds, impure, and confusedly mixed with gravel.
2. Sandy marl, one foot.
3. Green marl and concretionary limestone.
4. Irregular brown sandy bed, with green seams, one foot.
5. Irregular bed of concretionary limestone, very impure, and much mixed with green, red, and violet coloured marls, some of which are penetrated by veins of carbonate of lime, with pyrites, eight feet.
6. Strong bed of yellowish-grey limestone, ten feet. This bed contains more calcareous matter than the others; but many parts of it are distinctly concretionary, and much mixed with green pyritous marl. Portions of it are quartz, contain chalcedonic veins, and small flattened cells, coated over with mammillated reddish chalcedony. Other portions exhibit a compact yellowish-grey limestone, marked with dendridic stains. The whole is penetrated by veins of carbonate of lime, which sometimes aggregates in balls, exhibiting diverging radii.

7. Below the limestone is a system of beds of sandstone, which may be traced up the river, and which are of considerable thickness. They are chiefly composed of a brownish sandstone, streaked with red, passing into a pebbly conglomerate. It is associated with beds of a firmer texture; and half a mile farther up the river are some inferior beds of fine texture, and pink colour, which make a good building stone.*

On the Findhorn, near Altyre, the fish beds of the old red sandstone abound in fossils. Several new species have here been discovered through the zeal and perseverance of Lady Gordon Cumming. Similar fossiliferous beds are also found at Lethen.

INVERNESS-SHIRE.—The same old red sandstone formation, already described, extends along the lower or northern part of this large county, stretching along the south-eastern shores of the Firth, passing the town of Inverness, and terminating about the upper head of Lochness, in the primary and granitic range surrounding Fort-Augustus. A few miles west of Inverness, the sandstone conglomerate rests on the schistose rocks, which again are here seen to repose on a reddish coloured granite.

At Kilmuir, on the western edge of Lochness, the red sandstone again appears, and extends southwards, rising to the summit of the conspicuous mountain Mealfourvonie. According to Messrs Murchison and Sedgwick, a sandstone, associated with the bituminous schist of Caithness, prevails to the south-east of Inverness.

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* Sedgwick and Murchison, Geological Transactions, vol. iii.

In the neighbourhood of Beauly, the sandstone of Easter Ross appears to rest on the primary rocks, which prevail uninterruptedly to the westward. The valley of the Aird is covered with a deep and rich alluvial soil deposited from the river Beauly, and the county is fertile and beautiful.

EASTER ROSS.—This portion of Ross-shire forms a peninsula, being bounded on the south by the Moray Firth, and on the north by the Firth and Bay of Cromarty.

Two remarkable hills, the *Sutors*, form the entrance to the Firth on both sides. These hills are of gneiss, and, by the agency of their elevation, the sandstone strata above have been raised, and completely exposed to view.

Between the southern Sutor and the village of Cromarty, the sandstone strata have been turned into a completely vertical position, so that the succession of the beds can be readily traced. At the northern Sutor the beds are elevated in a nearly horizontal position. On the southern coast, again, on the banks of the Ethie Burn, a different position of the strata is displayed. These sandstone beds have been divided into three portions, a lower, a middle, and an upper.*

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* Millar on the Old Red Sandstone. Edinburgh, 1841.

The lowest bed rests on the gneiss. It consists of a coarse conglomerate sandstone; a bed of bituminous shale, with nodules containing fishes, surmounted by another bed of coarse-grained sandstone.

The list of fishes embraces *osteolepis, dipterus, glyptolepis, diplopteris, cheirolepis, cheiracanthis, pterichthys, coccosteus.* Impressions of *fuci* are also seen in some of the nodules of this bed.

The middle bed is composed of a coarse greyish sandstone, and is supposed to be equivalent to the grey sandstone of Forfarshire and Fifeshire. No organic remains have been discovered in this locality. The upper bed contains impure limestone, and a yellowish sandstone, corresponding to the upper beds of the red sandstone in the counties already alluded to. The depths of these deposits, as seen in the apparently undisturbed and horizontal strata of the northern Sutor, are as follow, commencing from above:

1. Soft arenaceous stone, with alternating beds of limestone, 500 feet.
2. Limestone and stratified clay, twenty-seven feet,—fish beds.
3. Coarse sandstone, 114 feet, reddish-yellow.
4. Bed of conglomerate, 215 feet, resting on gneiss.

At the northern Sutor, and on the south shore of the southern Sutor, are seen strata of lias limestone, resting, but at an unconformable angle, on the red sandstone. This lias is of a dark blue, or blackish colour, with frequent alternating laminæ of clay. It is full of organic remains, consisting of several species of belemnites, ammonites, and gryphites, with numerous species of univalves. Among the vegetable remains we found a frond of a large *zamia.* There are no traces of oolite above; but, indeed, it is only the outcrop of the lias strata that becomes visible at low water, and the existence of superincumbent strata cannot therefore be ascertained.

The red sandstone formation extends westward along both sides of the Firth of Cromarty, covered, in many places, with a deep deluvium of reddish clay, with large boulders of the primary rocks intermixed. This deluvium is seen in an immense accumulation, and assuming somewhat of a stratified form in the gorge leading to the village of Rosemarkie, on the north shore of the Moray Firth. At Strathpeffer, a few miles west of Dingwall, a dark-coloured calcareo-bituminous schist, foliated, and sometimes contorted, much mixed with iron pyrites, prevails, and from this shale arise the springs of sulphuretted hydrogenous water, for which this locality is famous. Here also is Ben Wyvis, one of the highest of the north-western hills. It is composed of primary schists flanked with the old red sandstone conglomerate.

Beyond this, both to the west and north, is a region of gneiss, mica schist, and quartz rock, till the old red sandstone again appears skirting the sea-coast from Cape Wrath to the eastern end of Sky.

SUTHERLANDSHIRE.—The surface of this county is very irregular and hilly. The centre is composed of primary schists, with granite and quartz rock, while the southern and north-western shores are fringed with the same old red sandstone already so frequently alluded to. The shores along the Dornoch Firth are composed of this material, which continues till we approach Dunrobin Castle, when an entirely new series, the oolite, makes its appearance, in which is situated the

Brora Coal-field.—The strata connected with this coal deposit begin to rise from the sandy shore between Golspie and Dunrobin, and extend to the mountain called the Ord of Caithness. This tract may be divided into three semi-elliptical valleys, that of Brora, Loth, and Navidale.* The first is bounded on the south-west by the mountain of Ben-a-Bhraggie, and on the west by the hills of Uppal, Loch Brora, and Clyne, all composed of red conglomerate. It is generally horizontal on the summits of the hills, or deposited on the sides with a slight inclination to the east. On the north-east of Loch Brora, this red conglomerate gradually passes inland in a north-western direction, forming the cap of some of the higher mountains. The low country of the coast is thenceforward bounded by an unstratified granitic rock, which is first seen near the church of Clyne, whence it sweeps down to the coast at Colyburn, there interrupting the stratified beds to be described afterwards, and then inclosing the vale of Brora. Again retiring from the coast, it continues to mark the interior boundary of the vales of Loth and Navidale, separating them by its advance at Portgower, and terminating the secondary series at the Ord of Caithness. This rock is throughout the greater part of its extent composed of reddish felspar and grey quartz, which are more or less accompanied by a decomposed green substance, probably mica. The surface of the valleys is covered with vast quantities of deluvial gravel, so as in most cases to conceal the underlying strata. The relations between the superior strata and the red sandstone cannot be observed in the Brora district, because the lowest beds in the former, dipping under the sea, are considerably above the base of the series to be afterwards described; but the junction between the granitic rock and the superior strata is seen in several places along the interior boundary of the valleys where the sandstone and shale rest, highly inclined or dislocated upon the edge of the mountain range. This is visible in the channel of a stream near Clyne church.

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* Murchison, Geological Transactions, vol. ii., second series.

Brora district is eight miles in length from Golspie to Colyburn, and about two and a half miles in its greatest breadth. A section made by the river Brora exhibits, 1. A mass of deluvium; 2. Yellow micaceous sandstone, and darkmic aceous shale, with belemnites. The white sandstone of Brambury Hill is quarried for exportation, and seems an isolated mass. It consists of beds of a compact beautifully white stone, and of beds of a quartzose or flinty stone, which are used for flints. Numerous casts of fossils abound—three species of *pecten,* a new species of *ammonite,* a *belemnite, melania trigonia terebratula;* also large stems of plants. This sandstone seems identical with the calcareous grit of Yorkshire. In descending from these quarries to the coal-pit, some of the intervening strata are concealed by deluvium, but as those beds, with their fossils, are exposed in various reefs along the coast, they have been arranged and identified with the succession of the strata in Yorkshire.

Below the sandstone just described there are the calcareous grit, the Yorkshire analogue consists of shale, with fossils of the Oxford clay, Kelloway rock, Cornbrash, coal grit, pier stone the equivalent of the great oolite, sandstone and shale, with *equisetum columnare,* and various seams of coal. The coal-pit is situated at the base of the sand and shale cliffs. The shaft is sunk 230 feet. The borings of 1814 were to the depth of 338 feet. The beds, forming the roof of the coal, are two and a half feet thick, the upper strata are full of fossil shells, the lower of leaves and stems of vegetables.

Of twenty-four species of the shells, sixteen are identical with the English oolitic beds. To this succeeds a bituminous matter approaching to jet, which forms the great bed of coal. It is about three and a half feet in thickness, containing in the middle a layer of shale highly charged with pyrites, which, if not carefully excluded, destroys the utility of the coals as fuel, and when mixed up with the mass and wetted, not unfrequently causes spontaneous combustion. A fault limits the coal-field to the west. This coal is a lignite or jet, and on being pulverized assumes a red ferruginous tinge.

The beds in contact with the granitic range are about one mile and a half distant from the pit.

This coal was first wrought in 1598 by Jane Countess of Sutherland. It has since been wrought at several periods, but to so little advantage, that we believe it is now abandoned.

The coast section north-east of the Brora pit exhibits the oolitic strata with their characteristic fossils. Near Dunrobin Castle, the calcareous sandstones are succeeded by calciferous grit; these grits are overlaid by sandstone and micaceous shales, with *ammonites* and *belemnites,* and these again are succeeded by black and white sandstone and shale, with a dark fossiliferous limestone. The fossils of these reefs are similar to those of the Oxford clay.

At Strathsteven a pure white sandstone is quarried to the depth of thirty feet. In it are small seams of coal.

At Kintradwell are beds differing from any of the previous, and analogous to the Cornbrash limestone and forest marble; the prevailing fossils are *avicula inequivalvis* and *terebratula inconstans.* A bed of shelly limestone, covered with shale, is succeeded by reefs of calciferous grits, containing fossils, and traversed by a band of quartz rock.

Loth valley is about six miles in length, and trough-shaped. The lowest part of the valley contains a black shale. The cliffs at the mouth of the Lithbeg Burn consist of black and white soft sandstone; at Kilmot the shelly limestone reappears; and at Kilgour Point the reefs consist of the shelly limestone and grits.

Near the limekilns at Portgower the strata have suffered great dislocation.

Navidale.—The granitic mountains retire gradually from Helmsdale, and again advance to the coast at the Ord of Caithness, thus inclosing this little valley. The base of the cliff near which stands Navidale House is composed of shelly limestone, which resembles some beds of the oolite, near Bath. Above this limestone the sandstone is in contact with the granite, and highly inclined. In proceeding to the north-east, the place of the shelly limestone on the shore is occupied by a conglomerate much more coarse than that near Portgower, and apparently derived from all the strata which have been described as occurring from Kintradwell to Navidale. The indurated shales might be mistaken for greywacke, but they are only the sandy shales altered by the intrusion of the igneous rock. From the altered state of the oolite strata, however, from the contact of granite, the inference is, that this igneous rock has been of later origin than the oolites.

Caithness-shire.—The surface of the county is more uniform and flat than that of Sutherlandshire. It forms an irregular triangle, of which the points are the Ord of Caithness, on the south, Duncansby Head, on the north, and Strathy Head, on the north-west. This space is composed almost entirely of the old red sandstone formation, resting on the granite and gneiss rocks to the south and westward.

The old red sandstone conglomerate, common to the other counties already described, here forms the lowest bed, and rests on the primary schists; to this succeeds a schistose sandstone, with bituminous shale, and a red sandstone forms the uppermost bed.

The old red conglomerate is seen on the north and north-western shores, both of Caithness and Sutherland. After doubling Cape Wrath from the west, and proceeding eastward, this conglomerate is first met with at Kerwick Bay, and stretches along the coast to Loch Durness, forming a succession of lofty precipices, which are frequently worn down into grotesque forms. From Loch Durness to Kyle of Tongue it disappears; but is met with again forming the conical hill of Craignavrecan, which rises to the height of 1200 feet. It is again seen at Port Skerry, from whence it penetrates into the interior. Further towards the south-east it forms the serrated chain of the Maiden Pap, 3500 feet above the sea-level, and still extends southwards till it skirts the quartz rocks of the Scarabins, and terminates at the granite of the Ord. To the eastward of the county it is concealed by the overlying upper beds of shale and red sandstone. This conglomerate is almost entirely composed of fragments of granite and quartz, united by a red-coloured argillaceous cement, with occasionally green earth. It also contains subordinate beds of a red coarse-grained sandstone, flagstones, and red marl. Through the intervention of these beds of red sandstone, it sometimes passes into the second or slaty formation.

Bituminous Schists.—This formation lies above the conglomerate, and is of great thickness. It consists of alternating beds of silicious and calcareo-silicious flagstones, dark foliated bituminous limestone, pyritous shale, and a bluish and grey close-grained micaceous sandstone. In this formation are found abundance of fossil fishes, the same as those already enumerated in the Ross-shire lower beds. These fossil fish occur invariably in beds of dark grey calcareous schists, highly bituminous and micaceous, immediately overlying the roofing-slates; and among other localities are found at Banniskirk, Widel, Clythe, Lybster, Latheron-Wheel. Those found at Banniskirk, on exposure to the air, change their colour from a dark grey to a purple plumb colour.

The grey and brown beds of sandstone afford an excellent building-stone, and is extensively quarried for this purpose. The finer beds of the dark calcareous flagstones are used for roofing-slates, and are imported under the name of Caithness slates. They are chiefly composed of alumine, silex, and mica, with a portion of lime and iron pyrites. They are extensively quarried at Banniskirk and at Castle Hill in Dunnet Bay.

Limestone is also quarried in several places within the county.

In this deposit there are no appearances of marine shells or coral, but occasionally traces of terrestrial vegetables are met with, and a fossil allied to the tortoise, supposed a species of Trionyx, probably of fresh-water origin, was also discovered some years ago.

To the schistose beds succeeds a formation of red, brown, and variegated sandstone, seen at Dunnet Head, and which also reappears on the opposite islands of Orkney, forming the upper strata of the elevated cliffs on the shores of the Pentland Firth.

Western Coasts of Ross and Sutherland.—The outline of the western coast is very irregular, being indented by numerous arms of the sea, and projecting into various picturesque headlands. Mica schist and quartz rock prevail in the interior. This latter forms many of the mountains in this district, as the Benmore hills, in the neighbourhood of Loch Maree, the hills of Assynt, and the space of country between that and Loch Eribol. These hills are generally conical, bare, barren, and have a singular cold greyish look, as if covered with a thin coating of snow.

At Applecross the lias limestone of the Hebrides is seen resting on the old red sandstone. A section near Applecross mill exposes the following beds:

1. Beds of shale and sand slightly calcareous, with many imperfect fossils.
2. Calcareous grey gritty limestone, containing lignites, pentacrinites, gryphites, ammonites, pinnæ, &c.
3. Calcareous grey gritty limestone, compact quartzose—no organic remains.
4. White conglomerate, with quartz pebbles.
5. Impure calciferous grey gritty limestone.

6. Bluish limestone, with a structure approaching to oolite.*

Along the coast, and for many miles inland, the old red sandstone prevails. It is thus described by the late Dr Maculloch :

The general outline of this formation presents considerable variety. In many places the sandstone forms a smooth land, with an even continuous swelling outline like those of alluvial countries, although this coast is characteristically free of alluvial matter, and nothing is found covering the bare rock but the usual shallow mountain soil. In a regular progress from this tameness of outline, it forms hills of all dimensions, and of every variety of aspect, round, conical, ridged, or serrated, ultimately rising to the greatest average of the Scottish mountains. The independent positions of many of these hills form one of the most remarkable parts of the character of this formation. In many places they rise suddenly from a hilly land of moderate elevation, composed of gneiss, to a height of 1000 to 2000 feet, and separated from any similar hill by a space of many miles. This is the case in Sutherland and Ross-shire. In other places they form groups more or less condensed, but still separated from each other at their bases by the gneiss on which they rest. Where they are insulated they produce a very striking effect, of which examples occur in Suil

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* Geological Transactions, vol. ii.

Veinn and Coulebegg. Similarly powerful effects result from the suddenness of their rise, the summit, together with the whole declivity, being visible from the base. In this manner Slengach is seen from Loch Maree, presenting a very striking object, with an alpine effect rarely found in Scotland, where the foreshortening that results from a gradual declivity generally conceals the summit, and diminishes the apparent altitude. From this cause these summits of the mountains are all but inaccessible. In thus taking a general view of the western portions of the counties of Sutherland and Ross-shire, it appears that the country consists of a basis of gneiss, forming an irregular and hilly surface, which, in extreme cases, varies in elevation from 100 to 1500 feet, but which often presents a table land of considerable height, with inequalities of comparatively small account. On this base are placed various mountains, either far detached from each other, or collected in groups, and all rising to an average altitude of about 3000 feet above the level of the sea, or of 2000 feet above that of the gneiss. The stratification of these is either horizontal or slightly inclined, with a variety of dip in which the eastern prevails, while the declivities of the mountains, on all sides, consist of the broken ends of the strata. In no case does the declivity consist of the surface of a stratum, as in mountains of micaceous schist or gneiss, on which it is usual to find the opposed declivities formed alternately of the surfaces and of the edges of the beds. "It is scarcely necessary to say," adds Dr Maculloch, "that the mountains so formed could not have been produced by the elevation of the strata, as in the last named rocks, and it is, on the contrary, evident, that, like mountains of trap, they owe their present shape to the abrasion of the sides. It follows, therefore, that the whole of this county has been once covered with a body of sandstone equal in thickness, in certain points, at least, to the present remaining portions, the variations of the dip marking the undulations of that mass when in its entire state. The extreme depth of this deposit, so far as it now can be discovered, may be measured by Kea Cloch, which appears to be between 3500 and 3700 feet."

THE WESTERN ISLANDS.

These islands exceed 300, of various size and form, scattered apparently indiscriminately amid the ocean. Geologically considered, however, they will be found to have certain natural relations to each other, by which they may be divided into groups. Four of these groups are well marked: 1st, The gneiss islands; 2d, The trap; 3d, The sandstone; 4th, The schistose; a 5th, The Clyde islands, are assimilated partly by their geographical position, and partly by the resemblance of their structure. These islands generally partake of the north-easterly tendency, which the whole mainland of Scotland assumes, not only in its shores, but in its mountains and valleys. We shall proceed to describe shortly the different groups.

THE GNEISS ISLANDS.

This group consists of the following islands:

Iona,
Tiree,
Coll,
Barra,
Vatersa,
Sandera,
Pabba,
Muldonich,
Mingale,
Bernera,
Eriska,
Fudia,
Hellesa,
Gigay,
South Uist,
West Rona,
Benbecula,
North Uist,
West Rona,
Harris,
Taransa,
Scarpa,
Scalpa,
Lewis,
The Flannan Isle,
Sulisker,
North Rona,
East Rona.

The great chain of the outer Hebrides forms the main portion of this group; the next is the chain of Coll and Tiree, while Iona, separated from them by a wide channel, may almost be considered as independent. Rona, and the northern part of Rasay, present a tract equally independent, and far removed from all the others.

The chief characteristic of all these islands is the gneiss formation. The general aspect of this formation presents considerable variety. It often exhibits a dead level for a considerable space, as in Tiree, Benbecula, and other islands, the only access obtainable to the naked rock being from some pool of water, or accidental breach of the surface. Occasionally, as in Lewis, protuberant masses are seen breaking through the soil. These become, in other situations, as in Coll and Rona, so numerous, that, on a general view, nothing but a continuous extent of rock can be seen; the small quantity of herbage, with the occasional lakes that occupy the intermediate spaces, being only visible in the immediate vicinity of the spectator. These rocky hills rarely exceed an hundred feet in height. There are two principal varieties of gneiss prevailing in these islands, one of a granitic, and the other of a schistose structure. From the latter a soil is formed, and general features produced scarcely different from those which occur where micaceous schist is the substratum. The former is remarkable for its indestructibility, and hence arises the peculiar nakedness of the countries that are composed of it. Considering its near resemblance to granite, which is easily acted on by the elements, the causes of this power of resistance are not readily accounted for. To a certain extent they may consist, in its compact form, and in the absence of fissures during the access to frost. To this latter circumstance is owing the want of springs, so conspicuous throughout the Long Island, and the same considerably explains the deficiency of recent alluvia so general in the island of this group. The stratified disposition of the gneiss of these islands, and its conformity to the general bearing of the strata of the main land, point out the identity of their formation, and the elevating agencies which have formed both into dry land.

Veins of granite are frequently seen to intersect all the varieties of gneiss, but are most abundant in the granitic gneiss, causing in this latter much greater contortions than in the schistose gneiss. These veins are very frequently composed of graphic granite. The minerals found in the gneiss are garnet, actinolite, quartz, felspar, hornblende, fluor spar, zircon, tourmalin, epidote, molybdena, oxidulous iron, and iron pyrites.

IONA.—This island is more celebrated for its antiquarian associations than for its geological or natural qualities. It is about three miles in breadth, with a low surface, seldom rising 100 feet above the sea-level. From the town to beyond the Bay of Martyrs, the prevalent rock is a black compact clay slate, which occasionally contains hornblende; near its termination, it is traversed by a vein of black basalt. A few rocks of the same granite, found on the opposite corner of Mull, are visible on the shore below the Bay of Martyrs. Proceeding southwards amid strata intermediate between gneiss and clay slate, a mass of felspar rock, with a surface white from decomposition, is apparent. It is a hard compact felspar, or hornstone. At a short distance from this are the remains of a mass of marble, which has now almost disappeared, all the useful parts having been quarried out. The texture of this marble is compact, splintry, and the colours are of a greenish hue, mixed with streaks of green steatite and serpentine. This substance is found also on the shore, rounded into green mottled pebbles. The beds of rock which succeed, in proceeding northward, are almost in a vertical position, and are composed of clay slate, mixed with silicious matter, and with laminæ of quartz and felspar intermingled, the whole assuming the appearance of granitic veins. The remaining parts of the island consist of gneiss. *Epidote*, of a pale green or yellowish colour, is largely mixed with this gneiss.

TIREE AND COLL.—These islands are of considerable size, being twelve miles in length, flat, and the surface under cultivation. They are composed almost entirely of gneiss, intercepted frequently by granite veins. In the gneiss of Tiree are found nodules, or rather masses of limestone, of a reddish and bluish colour.

BARRA, BENBECULA, HARRIS, LEWIS.—These, and the subordinate islands, form the great chain of the outer Hebrides. They have all a uniform structure of gneiss, exhibiting it in its different varieties, from a rock, almost identical with granite, to a well marked schistose structure. Patches of primary limestone, and masses of compact felspar, are occasionally met with, and traces of trap veins are not uncommon.

In the neighbourhood of Stornoway, in the island of Lewis, the gneiss is found passing into clay, forming a compound rock, of which a similar kind is prevalent in North Uist. A conglomerate, composed of rolled pebbles of various sizes, many a foot and more in length, consisting of gneiss, quartz, and felspar, is seen at the point of Arnish and the Aird, reaching as far as Garbust. This conglomerate resembles that which is found on the Mainland of Scotland, separating the primary from the upper or newer strata.*

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* Dr Macculloch's Western Islands.

THE TRAP ISLANDS.

This group is so named from the nature of the predominant rock entering into the composition of the islands. These islands consist of

Rasay,
Flodda,
Skye,
Soa,
Pabba,
Guillemon,
Lunga,
Scalpa,
The Shiant or Holy Isles,
Canna,
Sanda Isle,
Rum,
Egg,
Muck,
Inch Kenneth,
Mull,
Ulva,
Gometra,
Colinsay,
Eorsa,
The Treshinish Isles,
Staffa,
St Kilda.

Two of these, Pabba and Inch Kenneth, contain no trap rocks; but they are so far similar to the others, in containing the more recent stratified rocks with which the trap is associated in the greater number of the other islands of the group.

These trap islands are obviously divided into two principal groups, Skye being the centre of the one and Mull of the other. These are, however, connected by detached masses, occupying either the intermediate islands, or parts of the continent. The Schiant Isles, and the remarkable rocks at Loch Maddy, are found at the outskirts of this boundary, while St Kilda may almost be excluded, on account of its remoteness and want of probable connexion.

Unlike the schistose islands, which, in their form and position, preserve a north-easterly bearing, corresponding to the line of coast of the Mainland, and which evidently depend on the direction of their strata, the trap islands will be found to be quite unconformable and irregular. This contrast is peculiarly remarkable in Skye, where the larger part of the island presents a tendency different from that of the smaller portion, the former consisting of trap, while the latter is composed of primary strata. The non-conformity of the outline of Mull is less apparent, yet its longest shore, which, together with the opposite land of Morven, includes the sound, will also be seen to form a large angle with the predominant lines of the western coast.

SKYE.—This island forms nearly a parallelogram in its general outline, although many parts of this outline are broken up by numerous indentations of the sea. Its extreme length is about forty-five miles. The surface is almost invariably hilly, and presents three distinct groups of mountains, separated by intervening tracts of land; the plain of Kilmuir, and a small tract near Loch Bracadale, being the only exceptions.

Commencing with the southern division, a continuous ridge is found extending from the point of Sleat, to Loch-in-Daal, where it suddenly subsides into a low tract, stretching northwards in the direction of Broadford. The general elevation of this ridge is upwards of 1200 feet. It is composed of gneiss, the lowest rock and greywacke slate, red sandstone, compact grey sandstone, or quartz rock, and common white quartz rock.

The flat tract into which the ridge of Sleat subsides is succeeded by a group of five hills, which rise to an elevation of 2000 feet, and are of the same composition as the ridge of Sleat.

This latter ridge is separated from the next elevated land to the north-west, by an irregular low tract, forming a valley parallel to it, and extending from the head of Loch Eishort towards the northern shore. A second irregular ridge succeeds to this, occupying the whole space from Swishnish point to Broadford, and beyond it, and followed by another parallel valley, that of Strath; but little elevated above the two seas, which it here separates. With the exception of some syenitic elevations, this whole valley consists of lias and oolite limestone, with its characteristic fossils of gryphites, ammonites, and terebratulites. The whole island north of this consists of trap rocks, including syenite. The most conspicuous part of the island is that immediately to the north of the valley of Strath, the mountains here ranging from 2000 to 3000 feet in height. This group of mountains is divided into two portions, differing more remarkably in appearance than in composition. By far the larger portion presents a set of tame and generally rounded outlines, particularly unpleasing to the eye, the hills being apart from each other, and having all a smooth blunt conical shape. They are of a reddish colour, from the decomposition of the syenite of which they are composed, and which is largely imbued with iron. The other hills are, on the contrary, of a dark colour, approaching to black, which adds much to the rugged aspect of their bold and steep outlines. These form pinnacles and crags, projecting into bold fantastic shapes. The chief part of the dark group consists of the Cuchullin hills. These form a curved ridge, rising from the shores of Loch Brittle, and the Sound of Soa, with a rapid and rocky ascent. Some lower, but equally rocky hills, of similar composition and character, unite with them to inclose the lake Coruisk, while Blaven, forming a long acute ridge in a position still more easterly, rises above the whole, forming the highest mountain in the island.

To the northward of this group, on the western side, the land continues hilly, but is no longer mountainous, the general elevation not exceeding 600 or 800 feet.

Along the eastern shore from Loch Sligachan to

Loch Staffin, extends a shaly and impure sandstone and limestone, evidently belonging to the cornbrash, oolite, and lias formations. On the north-eastern shores of Loch Staffin is a fresh-water formation; in the shale, associated with the trap rocks, are flattened masses of shelly limestone, containing five species of *cyclas*, a *paludina*, *nerita*, *ostrea mytilus*, and some undescribed bivalves. No species of the cyclas, the paludina, and ostrea, are identical with the Weald fossils of the Isle of Wight.*

The interior, comprehending the district of Trotternish, contains trap mountains rising to an elevation of 2000 feet, and the highest point, the Storr, forms a very conspicuous and picturesque object. The celebrated Spar Cave is situated on the north-eastern shore of Strath Aird. The whole length of this cave, from the entrance to the extremity, is about 200 feet; a part of the interior is beautifully incrusted with stalactites, formed by the deposition of carbonate of lime from solution in water. Hence, in the pools in the floor of the cave, the natural processes of crystallization may be witnessed; numerous crystals of carbonate of lime assuming the rhomboid form being conspicuous.

At Talisker, a short and thin bed of coal, accompanied by bituminous wood, is found entangled in the trap rock. On the farm of Scorribreck, near Portree, coal is also found in several places among the trap, and along the shore at Portree harbour. Similar indications of coal are found near the head of Loch Gresornish and Dunvegan.

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* Murchison, Geological Transactions, vol. ii.

The minerals found in Skye are *analcime, chabasite, stilbite, olivine, prehnite, chalcedony, hypersthene, felspar, serpentine, quartz, marbles, &c.*

SCALPA, the adjoining island to Skye, is of an irregular oval shape, three miles by two in extent. It consists of a single mountain, with an uneven summit, and rounded outlines.

Red sandstone, interrupted by trap, and syenite rocks, and oolitic strata, rich in remains of testaceous molluscæ, constitute the whole of the island.

RASAY.—This island is fifteen miles in length, and in its widest part three miles in breadth. The northern extremity is formed of gneiss; next succeeds the red sandstone. The centre and western sides are occupied by porphyry rocks, and the low lying strata of the southern extremity is the oolite.

RUM.—This is a mountainous barren island, with an ungenial climate. Ben More, on the eastern side, is upwards of 2000 feet in height, Oreval, on the western side, is about 1800 feet. The northern side of the island is composed of old red sandstone, similar in appearance and dip to that of Skye. The southern half of the island consists of trap rocks, chiefly of that species called augite rock.

MULL.—This island is of an irregular form, being much indented with arms of the sea. Its extreme length is about thirty miles. The greater part of the island is composed of trap rocks. The northern shores are irregular, rising to the height of 1200 to 1500 feet, exhibiting basaltic terraces, and trap veins, and dykes, exposed like ruined walls and castles, from the effects of the weather. The middle division of the island is more elevated, but composed of the same trap rocks, rising to a height of 2000 feet, forming high cliffs on the western shores, in which are numerous cavities or caves.

The south-western part of the island, called the Ross, is composed of primary strata. The extreme point is granite, on which reposes quartz rock and mica schist. With the exception of Arran, this is the only locality, in the Western Islands, where granite is found.

A narrow strip of lias and oolite ranges along the south-eastern shores of Mull, commencing a little east of Loch Spelin, and continuing onwards to Loch Buy. Along the whole of this range it occupies the lowest position on the shore projecting near the level of the sea, so far from the cliffs as in general to admit of a passage along their base. Small patches of coal have also been discovered at Carsaig.

The oolitic strata are also observable on the western shores of the island at Gribon, opposite to Inch Kenneth. This small island is wholly composed of an oolitic sandstone and conglomerate, with the exception of a patch of gneiss on its western shore.

Ulva, Gometra, Colonsay, and Erosa, small islands in the vicinity of Mull, partake of the same geological character as that island. Ulva and Gometra are separated from each other by so narrow a sound, that from most points of view they seem to constitute an island. Ulva attains an elevation of about 1400 feet, Gometra about 800. Both consist of repeated ranges of terraces, rising in succession from the shores to the summit. These consist of dark bluish masses of trap, sometimes assuming the regular columnar form. An amygdaloid rock also occurs, abounding in the zeolite family of minerals. Although these ranges seldom exceed twenty feet in height, they are very numerous, since they skirt the whole south-western shores of both the islands. They are never continuous for a great space, being separated into detached parts, which have, in many places, a very artificial appearance, resembling fragments of walls and ruined towers. They are often as regular as those of Staffa, although on a much less scale. In many places they afford elegant and picturesque objects, and in number, extent, and striking effect, are said by a good judge* not to be inferior to the Giant's Causeway in Ireland.

Staffa.—This celebrated island is of an irregu-

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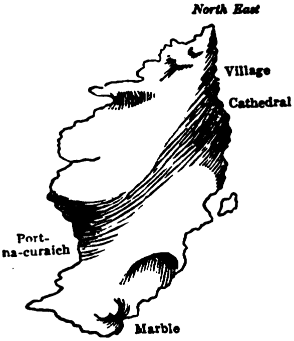
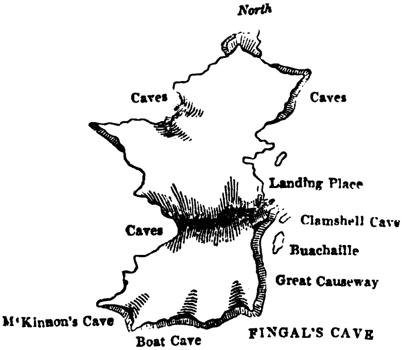
* Dr Maculloch.

ISLAND OF IONA.



STAFFA.



[*To face p.* 139.]

larly oval shape, and about a mile and a half in circumference, presenting an uneven table land, terminating nearly all round in cliffs of variable height. The greatest elevation is on the south-west, and amounts to about 144 feet. The island is covered with a rich verdure, and in summer is pastured by a few sheep and cattle, but no human habitation intrudes upon this domain of nature. The island is entirely of trap formation, and, as seen in section at its western extremity, presents the following aspect: The whole form is here divided into three distinct beds of trap of different characters, the lowest consisting of that conglomerate called trap tuff; the next of the great columnar range of dark greyish, or black basalt, composed of *augit* and compact felspar, minutely intermixed. The upper mass is an irregular mixture of small implicated and bent columns, with an amorphous basalt. These beds dip towards the east, that dip being most sensible, and most easily determined, in the lowest or conglomerate stratum, because its upper stratum is nearly straight. The thickness of the conglomerate, at the western side, at about a quarter-ebb, is fifty feet, necessarily diminishing as the bed extends eastward, until it reaches a point between the Great Cave and the Boat Cave, where it disappears under water. The columnar bed follows the inclination of the conglomerate, though not regularly, the upper surface being uneven, and the columns varying in height along the course of the stratum. Near M'Kinnon's Cave its thickness is only thirty-six feet, while, under the highest part near the Boat Cave, where the conglomerate sinks below the water, it is about fifty-four feet.

The columns are irregular in the number and position of their joints. Frequently they are entire throughout; sometimes they have slight marks of joints; while in other places these are not only numerous and decided, but notched in the usual manner, by the truncation of their angles. Besides these true joints, they are often cracked by oblique fissures. The number of sides varies, but the hexagonal and pentagonal are the predominant forms. These are intermixed with triangular trapezoidal and irregular prisms.

The usual and easiest landing-place is on the eastern side of the island adjoining to Mull. After landing, the visitor takes his course to the south and west end, along the base of the cliffs, and comes in succession to the Clam-shell Cave, the Island of Buachaille, or the Herdman, the Great Causeway, Fingal's Cave, the Boat Cave, and Mackinnon's, or the Cormorants' Cave.

The *Clam-shell Cave* is so called from its supposed resemblance to the well-known shell of this name. On entering the cave, on the left are seen a series of columns extending continuously to the length of forty feet, and bent into a semicircular form, while the wall, on the opposite side, is made up of the ends of innumerable projecting columns, presenting somewhat the appearance of a honeycomb. This cave extends inwards 130 feet, is thirty feet high, and about sixteen at the entrance. Its interior, however, possesses little of interest.

Buachaille, or the Herdman's Isle, is immediately in front of the Clam-shell Cave. At low-water, the best time for viewing it, it exhibits a series of small columns rising up from a base of arched and horizontal cones, and meeting at the top so as to form a cone. The regularity and symmetry of this rock renders it an object of peculiar interest.

The *Great Causeway*, a range of massive and perpendicular pillars, extends from the Herdman's Isle to the south-eastern corner of the island, where *Fingal's Cave* is situated. This is by far the greatest wonder of Staffa.

As its floor, in all states of the tide, is laved by the sea, the best way of viewing it is by a boat. Entering by a superb Gothic arch, sixty-six feet in height, and forty-two feet wide, the visitor is ushered into a long withdrawing hall, 227 feet long, with massive pillars rising up on all sides to the height of twenty and thirty-five feet. The green waters of the ocean form the floor, while from the roof depend various groups of pillars in every variety of angular and jointed shape. The effect produced by the contemplation of this magnificent temple cannot well be described. "Were it," says Dr Macullocb, "even destitute of that order and symmetry, that richness arising from multiplicity of parts combined with greatness of dimensions and simplicity of style, which it possesses,—still the prolonged length, the twilight gloom, half concealing the playful and varying effect of reflected light,—the echo of the measured surge, as it rises and falls,—the pellucid green of the water, and the profound and fairy solitude of the whole scene, could not fail strongly to impress a mind gifted with any sense of beauty in art or nature." The best view of the cave is on the right of the entrance and at low water. Its Gaelic name is Uaimh Binn, or "the Musical Cave;" that of Fingal being more recent.

The *Boat Cave* is situated about the centre of the west end of the island, and has been so called because it is accessible only by a boat and in calm weather. It is smaller than Fingal's Cave, being in height sixteen feet, breadth twelve feet, and length 150. Its interior is smooth and uniform, and possesses no very great interest; the columns of the entrance are, however, very symmetrical.

Mackinnon's Cave, called also the Cormorants', from the numbers of these birds which take up their abode in it, is situated at the south-west corner of the island. This cave is of easy access by water. Its exterior is spacious, and clustered with regular columns; but its interior is less magnificent than the great cave already described, possessing less order and regularity of columns. Its height is fifty feet, breadth forty-eight, and length 224 feet. Along the shores of the other parts of this singular island there are also numerous hollows and caves, all possessing a basaltic and columnar structure; but, after having seen those enumerated, there is nothing very remarkable in the appearance of the latter.

The Sandstone Islands are so exactly similar to the old red sandstone beds of the Mainland, of which, indeed, they form detached portions, that we deem it unnecessary to go into any detail concerning them. They are small and few in number.

THE SCHISTOSE ISLANDS.

These consist of

Inish Capel,
Kerrera,
Seil,
Luing,
Torsa,
Scarba,
Jura,
Isla,
Colonsay and Oronsay,

Shuna,
The Garveloch Isles,
Lunga,
Lismore,
Craignish Isles,
St Cormack,
Gigha and Cara.

The whole of this group possesses a common character, although there may be individual diversities, the island of Lismore forming an exception.

They may be classified according to their peculiar features thus:—

The first subordinate division may be called the *Slate Isles*, including Kerrera, Seil, Luing, and Torsa. Shuna, which is geographically and popularly associated with these, belongs strictly to the third subdivision. The characteristic of this group is the prevalence of clay slate. The next subdivision is the *Quartz Isles*, comprising Lunga, Scarba, Jura, and Isla, to which Colonsay, Oransay, and the Garveloch Isles may be added, the principal chain being characterized by the prevalence of quartz rock. The last subdivision includes, together with Shuna, the Craignish Isles, the Isles of St Cormack, Gigha, and Cara, and is distinguished by a series of schistose rocks, in which chlorite schist predominates, and which occupies an extensive tract on the adjoining Mainland. The islands of Kerrera and Seil form the immediate bond of union between Mull and the Argyleshire coast, containing the trap rocks of the one, and the schistose strata of the other. A very small portion also of the oolitic formation occurs in the three northernmost; but in parts so detached and minute, that they almost disappear in the particular details. The most obvious bond of connection consists in the trap, which prevails in the northernmost islands, and on the shores of the Mainland immediately opposed to them. The rocks of this family, from their analogy in position, correspondence in structure, and geographical proximity, seem to be detached parts of the trap of Mull and Morven.

KERRERA.—This island lies opposite Oban, skirting the coast of Argyleshire, and is four miles long, and two broad; the surface is extremely irregular, formed of a succession of small hills and hollows. The lowest rock is clay slate, which may be seen on the shore, as well as in some of the elevated ground in the interior. This slate is the same as that on the islands of Seil and Eisdale, where it is quarried for the purposes of roofing-slate. To this succeeds a greywacke slate, consisting of fragments of schists of different colours, cemented by a base of the same materials, more minutely divided. Above this are found two beds of sandstone, the lowermost being a red sandstone, the uppermost a grey sandstone conglomerate, containing innumerable pebbles and fragments of the different varieties of trap rocks, as also pebbles of granite and quartz, of different colours and textures. Trap rocks, of apparently three successive dates, pervade or overlie the strata, from the clay slate to the red sandstone conglomerate.

SEIL is composed of argillaceous schist, which is seen on both sides of the small islands; between these schistose beds is interposed a stratified mass, consisting of a mixture of pale grey compact felspar, with a greenish hornblende. The rocks which accompany this, and which form the remainder of a central ridge, are a quartz rock, with mica and chlorite schists. Trap rocks overlie the whole.

LISMORE.—This island is situated in the Bay of Oban, at the mouth of Loch Linnhe. It is eight miles in length, of irregular surface, and not much elevated. The whole island consists of a stratified blue primary limestone interlaminated occasionally with clay slate. The general direction of the strata lies north-east and south-west. It is in many places, however, very irregular and contorted. Veins of quartz and calcareous spar, as well as veins of trap, traverse the limestone in all directions. The surface of the island is fertile and cultivated.

JURA is among the largest of the Western Islands, and is conspicuous at a distance, not less from its size, than from the form of its mountains. Its extreme length is twenty miles, and its breadth, at the southern end, eight miles, which gradually decreases to the northern end, where it is only two miles. It presents the appearance of a long mountain ridge, elevated in the middle, and sloping on each side to the sea, without any intervening plains. The three hills on the south side, called the Paps of Jura, rise to a height of about 2500 feet.

The central ridge of the island is composed of quartz rock; to this succeed mica schist, chlorite schist, talcose schist, clay slate, and greywacke. Trap veins of great size, and continuous extent, are also found in the island. On the eastern side of the island is found that variety of clay slate known as drawing slate, or black chalk.

Isla.—This island is twenty-five miles long, and twenty in its greatest breadth. The general surface is even and uniform, with little picturesque beauty. A section of Isla, from east to west, presents two ridges. In geological structure, each of these ridges resembles the main ridge of Jura. That is, in the centre, quartz rock prevails, while on each side are strata of mica slate, clay slate, chlorite slate, &c. The south-western district is mainly composed of clay slate. The middle division of the island is chiefly composed of limestone. There are three kinds of this limestone; 1st, A blue schistose, which forms, perhaps, nine-tenths of the whole. This limestone is similar to that which is found in many of the primary strata of Scotland. It is everywhere interfoliated with clay slate in different proportions, and is of a lead blue colour, traversed by white veins; 2d, A grey whitish limestone, interfoliating with the micaceous schist, but in small quantity; 3d, A compact greyish, or ochrey-white limestone, associated with the quartz rock, but not interfoliated with it, as is the case with the others, but partaking of the silicious quality of the quartz rock at their points of junction.

Trap veins intersect the island, and are particularly abundant on the shore between Balachar and Macarthur's Head.

Lead ore, intermixed with copper pyrites, is found in the limestone in the neighbourhood of Portaskey, which has been wrought in ancient times, as well as at no very distant period. Beds of brown hematite also exist in the limestone of Lossit Hill.

COLONSAY AND ORANSAY, small islands to the north of Isla, are composed almost entirely of a micaceous schist approximating to chlorite schist.

THE CRAIGNISH ISLES.—Under this title is included upwards of twenty small islands, which lie within the Loch of Craignish. These are very picturesque islands, wooded, and bearing marks of having, at one time, been entirely covered with an oak forest. They are almost entirely composed of chlorite schist, with a small proportion of quartz rock and mica schist. Occasionally the chlorite schist contains hornblende and actinolite, and this gradually passes into hornblende schist.

SHUNA, situated between Luig and the Mainland, is about three miles in extent. It also contains chlorite schist, though the prevailing rocks are micaceous schist and quartz rock.

Gigha and Cara are composed chiefly of chlorite schist.

CLYDE ISLANDS.

These islands are grouped here more for their geographical position than from their geological affinity. They will be found, however, to have several connecting links in their formation, and may be thus classified:

- Arran,
- Lamlash,
- Sanda,
- Pladda,
- Bute,
- Inchmarnoch,
- Cumbray, (Great)
- Cumbray, (Little)
- Ailsa.

Arran.—This island is no less celebrated for its picturesque beauty than for the singular display of geological strata which its numerous coast sections exhibit. It may, indeed, be said to exhibit, on a small scale, an epitome of the geology of Scotland, where the relative positions and successions of the different strata are seen at one view.* Arran is about twenty miles in length, by ten in breadth, with a form nearly that of a parallelogram. The prevailing line of the shores is low, although, in some places, they present abrupt precipices. The island may be divided into two distinct parts, a mountainous or primary, and a hilly or secondary. The former occupies the north, and being bounded by an irregular line drawn between Whitefarland and Brodick, the remainder of the island belongs to the secondary or hilly division. Goatfell, the highest land in the island, is 2865 feet high, and the principal surrounding summits, in this northern division, are little inferior in height. These towering mountains have a noble and picturesque effect, and few scenes can vie in sombre sublimity with the deep and shaded Glen Sannox. Brodick Bay presents a scene no less interesting, though of a softer and more beautiful description. The conical summit of Goatfell forms the extreme outline of this picture, while the middle ground consists of a rich valley, with cottages and trees covering the gentle acclivities of the hills on one side, while, on the other, is the circular expanse of the ocean, forming a distant vista of its blue waters, and enlivened with the occasional passage of boats and ships. At Scriden, near Sannox, a large portion of the mountain has fallen from above, strewing the long declivity with immense masses of fragments, which, in their progress, have covered the shore with ruins, and which form numerous picturesque objects at every turn along the shore.

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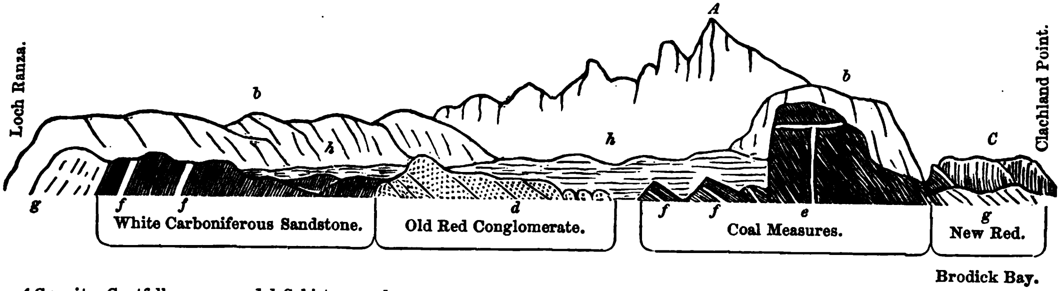
* Account of Arran by Professor Jameson; Dr Macculloch's Western Islands; Messrs Sedgwick and Murchison, Geological Transactions, vol. iii.

If a line be drawn from the south side of Brodick Bay to Machrie Water, it will divide the island into two nearly equal portions, which are alike distinguished by their external features and internal structure. The hills which rise in the interior of the southern region have generally neither a great elevation nor a striking form, and are almost exclusively composed of different varieties of trap. Near the eastern exterior are deposits of red sandstone, all apparently of one formation, and generally in a horizontal position, but overlaid, interrupted, and traversed by many masses of trap. In the northern region, on the contrary, all the central parts are occupied by lofty serrated mountains of granite, in the flanks of which repose a number of distinct formations, the subordinate beds of which are, in some places, much broken and contorted, and generally in a highly inclined position. All these several formations, from the granite to the newest stratified rocks, are occasionally traversed by trap dykes.

The northern, western, and southern slopes of the central mountains of granite are succeeded by chains of hills composed of different varieties of primary slate. On a part of the eastern slope, between North Sannox and the hills above Brodick Wood, the chain of schistose rocks is awanting, and masses of secondary conglomerate approach the base of the granite. From Iorsa Water to the south side of Calacol Bay, micaceous and chlorite schists occupy the coast. From Calacol Bay to near Loch Ranza, a quartzose variety of chlorite slate prevails. The mountains which rise north-east of Loch Ranza consist of primary schists; but they throw off and disappear in the upper part of the Glen of Loch Sannox. Above Brodick Wood, the zone of slate re-appears between the secondary formations and the granite, and ranges across the island to the Iorsa Water.

A coast section of the shore, from Loch Ranza to Clackland Point, exhibits the following strata, commencing on the left of the section of Loch Ranza; at *g* is a bed of red sandstone conglomerate, with beds of fine sandstone, forming round topped hills, 800 to 900 feet high; large fragments of this sandstone lie at the base, called the Scruten. Cock Scruten forms a well-known land-mark. This is supposed to be new red sandstone. Succeeding this, and having the same dip, is another bed of grey variegated blotchy marls, with ironstone nodules; towards the bottom it passes into a white freestone, the whole assuming the appearance of the carboniferous series; in it are six or eight thin beds of red limestone, *f f*, containing fossil shells of productus and spiriferæ, with corals; below these follow a succession of white sandstones, passing into coal-shale, with bands of fossiliferous limestone.

SECTION OF ARRAN FROM LOCH RANZA TO CLACHLAND POINT.



A Granite, Goatfell. *b b* Schistose rocks. *fff* Limestone. *C* Trap rocks. *d* Old red sandstone conglomerate. *e* Trap vein. *g g* New red sandstone, with porphyritic veins. *h h* Diluvium.

These beds rest on the schist mountains, and are of considerable extent. White grits, and white sandstone and shale, follow, with numerous trap veins and dykes. The old red sandstone beds, *d*, follow, by an imperceptible gradation. At Groggan Point, the character of this deposit becomes decisive. There is an absence of all vegetable remains, below is greywacke, and above a limestone corresponding to cornstone.

At the north end of the village of Corry are seen beds of white sandstone and grit; to this succeeds the mountain limestone, *f f*, which, at this place, is extensively quarried. There are about twenty of these beds, from eight to ten inches thick, separated by bands of red shale, the whole surmounted by magnesian limestone of four feet in thickness. Among the fossils are the large *producta Scotici*, *spirifer striatus*, *cardium alæformæ*, large *encrinites*, and *madrepores;* to these beds succeed sandstone and sandstone-grits, with shale and limestone, much disturbed by trap dykes.

The coal measures next appear, elevated 1000 feet above the sea, as at Meal Doun; *e* is a trap dyke, which traverses the strata here. Beyond Brodick village, the coal measures are cut off, and are succeeded by a mass of diluvium, *h*. Behind, in Glen Shiragh, is seen the old red sandstone re-appearing, while, on the coast line, the new red sandstone *g* succeeds the coal measures, intersected by numerous trap dykes and veins.

LAMLASH, a small island adjoining to Arran, is composed of porphyry.

PLADDA consists of a mass of greenstone.

BUTE lies contiguous to the Argyleshire coast, to which it is intimately associated, not only in contiguity, but in geological formation.

The length of the island is about eighteen miles, and its general breadth about four miles. It is naturally divided into three parts. The Garroch Head consists of a rugged ridge of hills rising to an elevation of 600 to 800 feet, and composed almost solely of trap; a low narrow tract of alluvial matter separates this portion from the middle division. This consists of a rather low undulating fertile tract of land, composed of red sandstone. The northern division, which is separated from the last by a low valley, extending from Rothsay to Scalspie, is composed of various primary schistose rocks. An elevated ridge, forming the north-eastern part of the island, rises here to the height of 1000 feet. In this valley are two rivers of fresh-water, Lochs Fad and Stuck. Round the northern, or primary part of the island, the shores are generally low, and a flat margin bounds the eastern side. To the south of the town of Rothsay there is a similar flat, within which the sandstone and conglomerate form a range of cliffs of little elevation and small extent. The remainder of the shores of this division to the isthmus which separates it from Garroch Head are generally low, and there is reason to suppose that the sea once flowed in here between the two divisions.

The southern division, from Kilchattan Bay to Garroch Head, is composed of trap, divided into a number of parallel and straight narrow valleys, of which a principal one traverses the entire extent of the promontory, the whole of these being disposed in lines from north-west to south-east, in a direction conforming to the general bearing of the island.

The northern, or *primary* portion of the island, is interesting, as illustrative of the corresponding formations on the Mainland. A glance at the accompanying map will point out the line of continuity of the strata better than any description.

The northernmost portion consists of micaceous and chlorite schists, identical with those of the adjoining Mainland. To this succeeds another schistose band, which is a continuation of that line of slaty rocks which extends from this point to Stonehaven, on the east coast of the island. This belt is composed of mica schist, chlorite schist, clay slate, greywacke, and incidental bands of limestone. These different strata pass gradually into each other. The old red sandstone formation immediately follows, and occupies the middle portion of Bute, as already mentioned. On the shore between Ascog and Rothsay, fragments of an irregular bed of limestone are found in the conglomerate; it is of a mottled grey colour, and at its boundaries graduates into the contiguous rock.

Trap veins traverse the sandstone in various situations. An interesting trap vein is seen a little above Kilchattan Bay, where several varieties of trap rocks traverse the vein, viz. greenstone, porphyry, containing very large crystals of glassy felspar, a tufaceous rock, a very fine basalt, and common greenstone. A partial seam of coal was at one time wrought at Ascog, on the east coast, but it was abandoned as unprofitable; indications of coal were also visible in the western side of the island at Scalspie. This island is remarkable for the almost total absence of all diluvial or alluvial matter, neither are any rolled stones of any magnitude any where to be seen.

The climate is very moist, but mild, and reckoned salubrious.

INCHMARNOCK, a small adjoining island, is composed of slate, which is here quarried, the same as on the Mainland.

THE CUMBRAY (GREAT) is three miles in extent, with a high and rather hilly surface. Its strata correspond with the middle region of Bute, consisting of the old red sandstone, traversed by trap veins.

CUMBRAY (LITTLE.) This island is separated from the former by a strait more than half a mile in breadth. It is of an irregularly triangular shape, and about two miles in extent. It is composed almost entirely of trap rocks, with a small patch of sandstone where the castle is built.

Ailsa is described in the notice of Ayrshire.

The following Table, arranged in the descending order, will point out the Secondary Formations, and their relative positions and localities, in the North of Scotland and the Western Islands:

I. *Chalk.* Flints, with fossil remains.	West of Peterhead.
II. *Blue clay* and *shale,* with fossils of the Weald-clay and Hastings-sand.	Loch Staffin, Skye; Linksfield, Elgin.
III. *Grit of Coral-rag.*	Braambury Hill, Brora, Sutherland.
IV. *Shale beds,* with fossils of Oxford clay.	Dunrobin Castle, Brora.
V. *Upper beds of great oolite,* resembling *cornbrash* and *forest marble.*	East coast of Trotternish, Skye. Beal, near Portree, do. Scrapidale, Rasay. Lhanbryde, near Elgin.
VI. *Great* and *inferior oolite,* upper sand and sandstone; lower, carboniferous shale and sandstone, with numerous fossils.	East coast of Trotternish and Rasay; Carsaig, Mull; Strathsteven, Brora, inferior shales, Brora coal-pits; cliffs opposite Portree, Skye; Holme Waterfall, do.; South coast of Mull.

VII. *Lias,* upper part, micaceous shales graduating into oolite; lower, blue limestone, fossils of gryphites, belemnites, ammonites, plagiostoma, &c.	Holme Cliff, Skye; Strath and Broadford, do.; Scalpa, Pabba, Carsaig and Tobermory, Mull; Cromarty Sutors; Applecross, coast of Morven; Lhanbryde, Elgin; Inverugie, do.
VIII. *New red sandstone and conglomerate.*	Inch Kenneth, and opposite coast of Mull; Arran; Tarbet Ness; Dunnet Head; and southern cliffs of Orkney, doubtful; perhaps upper beds of old red.
IX. *Old red sandstone.*	
(1.) Upper beds yellow, fine grained quartzose sandstone, with subordinate beds of silicious concretionary limestone, scales of *holoptychus* and *pterichthys.*	Quarrywood, Pluscarden, Covesea, Elgin; Ethie Burn, Cromarty; Stratheden, Fife.
(2.) Red marl and sandstone conglomerate, red compact sandstone, scales of *holoptychus.*	Scatcraig, Dipple, Elgin; Cromarty; Clashbinnie, Perth; Dairsie, Fife; Forfarshire, various localities.
(3.) Calcareo-bituminous schists, silicious flagstones, with *dipterus, osteolopis,* &c.	Castle Hill, Banniskirk, Lybster, Wick, Thurso, Caithness-shire; Coul, Inchcoulter, Geanies, Tulloch Castle, Ross-shire; Inches, Inverness.

Grey and red sandstone, bituminous shale, calcareous nodules, with fish, fuci, &c.	Cromarty; Lethen, Altyre, Elginshire; Gamrie, Banffshire.
Grey sandstone, with vegetable remains, argillaceous flagstones, with *cephalaspis.*	Forfarshire; Wormit Bay, Fifeshire, &c.
(4.) Sandstone conglomerate, red and grey ochrey alumino-silicious base, with masses of primary rocks imbedded.	Flanking the south side of Grampians; West coast of Argyleshire; Western Islands; Moray, Sutherland, Ross, Inverness, Caithness shires, &c.

Note.—New red sandstone is included in the table by Messrs Sedgwick and Murchison, Geological Transactions, vol. iii. as uncertain. The present position of the Caithness bituminous schists (No. 3.) is also partly conjectural and analogical. Perhaps their real position may be immediately after No. VIII. if they be really the equivalents of the coal measures.

THE ORKNEY ISLANDS.—This group consists of Pomona, or Mainland, Huoy, and a number of small, rather flat, and unpicturesque islands. The prevailing strata is the old red sandstone, with here and there the appearance of gneiss and the primary schists. The sandstone formation appears, in every respect, analogous to that of the adjoining county of Caithness, and, therefore, requires no particular description. The same fishes have been found in the grey sandstone slates of Pomona, as in the lower beds of the Cromarty and Caithness series. Together with these icthyolites are found a considerable quantity of vegetable carbonaceous remains. Many of them are apparently fuci, but others are cryptogamous land-plants, imperfectly preserved, but similar in general appearance to those which so largely pervade the Caithness slates. The fishes found in the quarries of Pomona have been enumerated by Dr Trail.*

SHETLAND ISLES.—This group consists of a central portion, called the Mainland, extending from Sumburgh-Head, on the south, to Feidland Point, on the north; of the islands Yell and Unst, extending still farther northwards, and forming almost a continuation of the Mainland, and of the islands of Fetlar, Walsey, Bressay, and numerous smaller islets on the east coast, with Papa Stour, Burra, Foula, and Fair Isle, in the west.

Roeness Hill, forming the north-west corner of the Mainland, consists of granite. This granite extends southwards through North Mavine to Meickle Voe, and is seen forming several of the detached rocks and islets, and again appears in the Mainland at Sandsting.

Immediately to the south-east of the granite of

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* Edinburgh Philosophical Journal.

Roeness Hill, is a syenitic greenstone extending to the island of Meickle Voe, on the south and eastward through the Mainland to Firth Voe, including also some parts of the small islands of Biga, Brothers, &c. To the west of the granite of North Mavine, and forming the whole remaining headland, is a mass of trap rocks, consisting of porphyritic and amygdaloidal claystone.

The middle portion of the Mainland is composed almost solely of gneiss, and the same formation extends throughout the island of Yell, and the western half of Unst.

To the south-east of the granite of Sandsting a syenitic and epidotic rock forms a portion of the small islets in the Bay of Scalloway, and the same rock is seen intersecting the Mainland of Quendal Bay. The southern promontory of the Mainland, from Hawksness to Fitful-Head, consists of clay slate and chlorite slate, with numerous bands of a greyish-blue primary limestone. A band of this limestone is also seen traversing the gneiss of the centra Mainland. The eastern half of the south promontory, from Rovie-Head to Sumburgh-Head, is composed of old red sandstone, which rests upon clay slate and chlorite slate.

The granite of Sandsting is succeeded on the west by a bluish-grey quartz rock. This, again, is followed by the old red sandstone and conglomerate which skirts the coast, and forms the whole of

Papa Stour. Interspersed with this sandstone are rocks of trap, porphyry, and amygdaloid. "At the island of Mousa, on the eastern coast," says Dr Hibbert, "two or more beds of a bluish limestone, from six to ten feet in thickness, may be observed to alternate with the sandstone, and at the head of Culbinsburgh Bay, in Bressay Island, several small spheroidal concretions were found imbedded in the sandstone. They were three or four inches in length, and highly indurated." These may not unlikely prove to be fish nodules.

Dr Hibbert describes the lower beds of the sandstone as grey-coloured, the upper red.

The western half of the islands of Unst and Fetlar are composed of gneiss and micaceous, talcose, and chlorite schists, while the eastern portions consist of serpentine and diallage rock, intermixed with the above schists.

In the sandstone at Sandlodge, copper mines were formerly wrought, but were in a short time abandoned. The principal vein, according to Dr Fleming, was nearly fourteen feet broad, extending from south-west to north-east. Towards the surface brown hematitic iron ore was found, intermixed with copper pyrites.

In the clay slate of Fitful-Head is a vein of iron mica, about twelve feet in thickness, traversing the hill in an easterly direction.

Dr Hibbert discovered the chromate of iron, so extensively employed in the arts as a pigment, in the hills in the vicinity of Balta Sound. It exists in insulated masses of various sizes in the serpentine rock.*

FOULA ISLAND consists of granite, gneiss, mica, and clay schists, occupying about one-third of the north-eastern portion, while the remainder is composed of a bluish-grey sandstone similar to the lower beds on the Mainland.

FAIR ISLE lies twenty-five miles south-south-west of the southern point of Shetland. It consists chiefly of sandstone, with greenstone. In the latter is a vein of copper pyrites.

Besides the minerals already enumerated, the Shetland Isles contain

Actynolite, fibrous leek-green, in beds or veins found on the banks of the Nithista.

A variety of *potstone* at same place.

Porphyry in veins traversing the gneiss.

Serpentine and *diallage* in the islands of Unst and Fetlar.

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* Dr Hibbert's Description of Shetland Islands, with Geological map, 4to. 1822.

GLOSSARY.

Aggregate—A solid mass of matter of the same or different kinds of substances joined together.

Alluvium—Earth, clay, sand, gravel, and stones, transported by currents, and deposited on the surface of strata. Diluvium has much the same signification, applied to older deposits.

Ammonite—An extinct molluscous animal allied to the modern nautilus, inhabiting a chambered cell, so called from its resemblance to the horns on the statues of Jupiter Ammon.

Amorphous—Bodies devoid of regular form, in contradistinction to crystallised bodies, &c.

Amygdaloid—A form of trap rock where lime, quartz, and other earths, appear imbedded like almonds in a cake.

Argillaceous—Clayey.

Augite—A simple mineral of a dark green or black colour.

Basalt—A trap rock, dark green or black, composed of augite and felspar.

Belemnite—An extinct molluscous animal, having a long straight chambered conical shell—from βελεμνον, a dart.

Bituminous Shale—A clayey slate, containing bitumen or pitch.

Bivalve—A shell with two valves.

Boulder Stones—Round blocks of detached stone, found on the surface, or imbedded in the soil, and which have been transported from a distance by currents of water or the action of glaciers.

Calc, or Calcareous Spar—Carbonate of lime crystallized.

Carboniferous—Strata containing coal, from *carbon*, charcoal.

Cetacea—The whale tribe.

Chert—A mixture of siliceous matter and limestone.

Claystone—A trap rock composed chiefly of clay.

Clinkstone, called also **Phonolite**—A trap rock, chiefly felspar.

Coal Formation, or **Coal Measures**—Terms applied to the strata containing seams of coal.

Columnar—Shaped like pillars or columns.

Comminuted—Worn down into minute particles.

Conchoidal—Hollow like a shell; applied to the fractured surfaces of rocks.

Conformable—When the planes of one set of strata are parallel to another, they are said to be conformable; but when the reverse, *unconformable*.

Conglomerate—A mass of rounded pebbles cemented together.

Coniferæ—Plants which, like the fir, bear cones.

Coprolites—Nodules containing the fæces of fish or reptiles.

Crop out—The rising up of strata to the surface.

Crustacea—Animals of the crab kind.

Cryptogamic—Plants, such as ferns, mosses, where there are no conspicuous flowers.

Debris—The mouldering fragments of rocks.

Denudation—The carrying away of the upper strata by the action of running water, by which the rocks below are laid bare.

Deposition, Deposited—Applied to sedimentary materials suspended in water, which have afterwards settled down and formed solid strata.

Dicotyledonous—Plants having two seed lobes, as the bean.

Dikes—Large veins of granite, or trap rocks, running through stratified rocks.

Diluvium—An accumulation of clay and debris of rocks of an earlier date than alluvium.

Dip—The inclination of a stratum from its perpendicular or horizontal position.

Disruption—A breaking through, or asunder.

Estuary—An arm of the sea, into which a river flows.

Extinct Animals—Beings that no longer exist as species on the earth; applied also to plants.

Fault—The sudden interruption of a stratum, by one end slipping below the other, or the intrusion of a vein or dike.

Felspar—Chiefly alumina or clay, an ingredient in granite and trap.

Formation—A group of rocks or strata of one age or period of production.

Fossils—The remains of animals or plants more or less converted into stone, as found in the rocks or soil.

Geology—From γη, the earth, and λογος, a discourse.

Gneiss—a stratified rock, composed of the same materials as granite.

Granite—an igneous rock, formed of quartz, felspar, and mica.

Greenstone—A trap rock composed of felspar and hornblende.

Greywacke—From *grau*, grey, and *wake*, a German provincial term. The lowest series of secondary rocks.

Grit—Coarse-grained sandstone.

Gypsum—Sulphate of lime, plaster of Paris.

HABITAT—The natural abode of an animal or plant.

HEMATITE—Liver-coloured iron ore.

HORNBLENDE—A simple mineral of a dark green or black colour—an ingredient of trap rocks.

HYPERSTHENE—From υπερ, above, and σθενος, strength; a rock of the hornblende family, very hard and dark-coloured.

ICHTHYOLITES—Fossil remains of fishes.

LACUSTRINE—From *lacus*, belonging to a lake.

LAMINAR—Disposed in thin leaves or layers.

LIAS—A provincial name for a clayey limestone.

LITTORAL—From *littus*, belonging to the shore.

LOCALITY—This term is applied to the place where any mineral or plant, or animal, is found naturally to exist. In Geology, to the districts or regions of the globe where particular formations of rocks occur, or to rocks containing particular minerals.

LYCOPODIACEÆ—Plants intermediate between ferns and the coniferæ. The fossil ones being of gigantic size.

MADREPORE—Corals, with star-shaped cavities.

MATRIX—The mass in which a mineral or fossil is fixed or imbedded—from *matrix*, a womb.

MECHANICAL ORIGIN—Rocks composed of particles that have been suspended in water not chemically dissolved.

MICA—A simple mineral, having a glittering silvery surface, an ingredient of granite.

MOLLUSCA—A division of the animal kingdom—those animals having a soft fleshy body, with no bones, as the oyster, snail.

MONOCOTYLEDONOUS—Plants with one seed lobe, as the common oat, palms, &c.

NODULE—A round mass, or little knot.

NUCLEUS—A solid centre, round which other matters collect.

OBSIDIAN—A kind of lava—volcanic glass.

OLIVINE—An olive coloured mineral found in lava and trap rocks.

OOLITE—An impure limestone formed of round bodies, like the roe of a fish, —from ωον, an egg, and λιθος, a stone.

ORGANIC REMAINS—Animals and plants found in the earth's strata, generally converted into stone, bitumen, &c.

ORTHOCERATITES—Extinct molluscous animals that inhabited a long chambered shell, like a straight horn.

PETRIFACTIONS—Substances converted into stone—from *petra*, a rock, and *factus*, made.

Pitch-stone—One of the trap rocks—so called from its resemblance to consolidated pitch.

Plutonic Rocks—Those formed by the action of heat; granite, trap, and volcanic rocks are so called, being produced from below in a fused state.

Porphyry—An igneous rock having crystals of felspar, or other earths imbedded in a common base—from πορφυρα, purple.

Precipitation—The separating and throwing down of substances from an aqueous solution.

Productus—An extinct animal, with a two-valved shell, found in the older rocks; analogous to the living terebratula.

Pyrites—(iron)—a sulpheret of iron.

Quartz—Silex or flint—a simple earth.

Quartz Rock—a rock composed of silicious particles, having a greyish stratified aspect.

Sandstone—Any stone composed of minute grains, or particles cemented together, generally applied to stones having the ingredients of granite—viz. felspar, quartz, and mica.

Saurian—Animals of the lizard tribe—from σαυρα, a lizard.

Schistose—Slaty.

Schist—From *schistus*, that can be split, a slate.

Sedimentary Rocks—Rocks formed by their particles being thrown down from a suspension in water, and then consolidated.

Silt—Mud deposited by rivers.

Stratum—pl. Strata. When several rocks lie like the leaves of a book, one upon another, each individual forms a stratum.

Subordinate—Applied to strata that are inferior in position, and inferior in extent or thickness to the principal beds of the same formation.

Syenite—A kind of granite containing hornblende.

Testaceous—Shell covered animals.

Till—Provincial term for diluvial clay.

Trap—A general term for Plutonic rocks, composed of felspar, augite, hornblende, and sometimes quartz.

Tuff, or Tuffa—A soft earthy rock of the trap family, or the scoriæ of modern volcanoes.

Univalve—Shells with one valve.

Vesicular—Formed into bladders or blisters—from *vesica*, a blister.

Wacke—A soft earthy variety of basalt.

Zoophytes—Corals, sponges, and other plant-like animals.

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